Draft

Lake Tahoe TMDL Source Category Group Work Plan

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California Regional Water Quality Control Board
Lahontan Region
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Acronyms

BLM	Bureau of Land Management
BMP	Best Management Practice
CARB	California Air Resources Board
CAREC	California Alpine Resort Environmental Cooperative
CONCEPTS	Conservational Channel Evolution and Pollutant Transport System
CTC	California Tahoe Conservancy
EIP	Environmental Improvement Program
EMC	Event Mean Concentration
EP	Erosion Potential
ERA	Equivalent Roaded Area
GIS	Geographic Information System
IERS	Integrated Environmental Restoration Services
IWQMS	Integrated Water Quality Management Strategy
kPa	Kilopascals
K_{sat}	Infiltration Capacity
LRM	Load Reduction Matrix
LRMAR	Load Reduction Matrix Analysis Report
LSPC	Loading Simulation Program in C++
LTBMU	Lake Tahoe Basin Management Unit
LTIMP	Lake Tahoe Interagency Monitoring Program
MT	Metric Ton
MTLR	Maximum Theoretical Load Reduction
NDEP	Nevada Division of Environmental Protection
nhc	Northwest Hydraulic Consultants
NOx	Oxides of nitrogen
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
PCO	Pollutant Control Option
PLRE-STS	Polutant Loading Reduction Estimator – Spreadsheet for Tahoe Stormwater
RWC	Residential Wood Combustion
SCG	Source Category Group

SCIC	Source Category Integration Committee
SEZ	Stream Environment Zone
STPUD	South Tahoe Public Utility District
SWQIC	Storm Water Quality Improvement Committee
TMDL	Total Maximum Daily Load
TRPA	Tahoe Regional Planning Agency
TSP	Total Suspended Particulates
TWG	Technical Working Group
UC	University of California
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
WEPP	Water Erosion Prediction Project

1. Introduction

Lake Tahoe is losing its famed clarity due to excess loading of fine sediments and nutrients. As a result, the California Regional Water Quality Control Board, Lahontan Region (Lahontan) and the Nevada Division of Environmental Protection (NDEP) initiated a total maximum daily load (TMDL) study, including a comprehensive research and restoration planning effort. The Lake Tahoe Clarity TMDL is an integral part of the overall Pathway 2007 planning process.

A major component of the TMDL study is developing an understanding of the sources of pollutants to the lake and quantifying these sources to the extent possible. To facilitate this process, Lahontan and NDEP has identified and assembled regional experts into Source Category Groups (SCGs) to investigate pollutant control options (PCOs) for each major source of pollutants entering Lake Tahoe. The five major sources are:

- Urban Uplands
- Forest Uplands
- Groundwater
- Atmospheric Deposition
- Stream Channel Erosion

This Work Plan describes the context for the SCG investigations, outlines the general approach for estimating Lake Tahoe Basin-wide pollutant load reduction potential, and presents Work Plans for each SCG.

1.1. TMDL Background

The Lake Tahoe Sediment and Nutrients TMDL was initiated in 2001, strategically building upon existing and ongoing research, monitoring, and modeling efforts. The TMDL is being developed in three phases. [1]

Phase 1

The results of the Phase 1 investigations are the determination of current pollutant loading to the lake as well as the Lake Tahoe Basin-wide load reductions needed to meet water quality standards. Phase 1 will conclude with the release of a Lake Clarity TMDL Technical Report in December 2006.

The scientific underpinnings of the TMDL include nearly four decades of lake clarity monitoring and stream flow and water quality monitoring for ten streams entering Lake Tahoe. These data and a wealth of supporting information and modeling have resulted in a refined pollutant budget for fine sediments and nutrients entering the lake (Table 1-1).

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[1] The use of the term “phase” in this Work Plan refers to the phases of the Lake Tahoe Clarity TMDL and is consistent with Lake Tahoe TMDL planning efforts over the past five years. The term phase has a different meaning in the context of the California Regional Water Quality Control Board TMDL program.

Table 1-1. Lake Tahoe Pollutant Budget

Source Category		Total Nitrogen		Total Phosphorus		Total Fine Sediment[1]	
		MT/year	Percent of Total	MT/year	Percent of Total	MT/year	Percent of Total
Upland Runoff	Stream Loading	97	25%	23	46%	6,900	47%
	Intervening Zones	30	8%	8	16%	2,200	15%
Stream Channel Erosion		10	2%	2	4%	3,800	25%
Atmospheric Deposition		203	51%	8	16%	1,400*	9%
Groundwater		50	13%	7	14%	NA	NA
Shoreline Erosion		2	1%	2	4%	500	4%
TOTAL		393		50		14,800	

[1] Fine sediment is defined as particles ≤63μm for all sources except Atmospheric Deposition, for which it is ≤30μm
MT = metric ton

The Lake Tahoe Clarity Model was developed by researchers at the University of California Davis (UC Davis). The Clarity Model uses a historic meteorological dataset as well as modeled and monitored pollutant loading estimates to predict lake clarity under different pollutant loading scenarios. Initial results indicate that a 30 to 40 percent reduction in pollutant loading from all sources could result in a lake clarity increase from approximately 23 meters to 30 meters of Secchi depth.

Phase 2

Phase 2 is focusing on the identification of load reduction opportunities and development of implementation and monitoring plans. The investigations described in this Work Plan are part of Phase 2. The results of the SCG efforts will form the basis for the development and selection of an Integrated Water Quality Management Strategy (IWQMS). Wasteload and load allocations, TMDL elements required by the Clean Water Act, will be based on the selected IWQMS. Allocations may be made to source categories, watersheds, programs, jurisdictions, or a combination of these. In addition, water quality trading will be analyzed as a programmatic means to assist implementation. Phase 2 will conclude with the adoption of the final TMDL in November 2008.

Phase 3

In Phase 3 the TMDL restoration plan will be implemented and new information will be incorporated into the analyses through continued monitoring, modeling, and research. The TMDL will be implemented through projects, programs and regulations included in the Tahoe Regional Planning Agency (TRPA) Regional Plan, the U.S. Forest Service (USFS) Forest Plan, state funding agency programs, and permits issued through Lahontan and NDEP. Load reduction credits related to projects and programs will be tracked and effectiveness monitored. Ongoing research and monitoring will improve the scientific basis for the TMDL and IWQMS over time. A formal Adaptive Management System will provide the platform for continuous improvement of load reduction estimates and for focusing implementation on effective and appropriate pollutant controls.

1.2. IWQMS Discussion

Lahontan and NDEP have contracted with Tetra Tech, Inc., to evaluate load reduction opportunities from the major sources of pollutants entering Lake Tahoe and to develop IWQMS alternatives that will result in meeting the lake clarity standard. These IWQMS alternatives will provide the basis for engaging project implementers and public stakeholders in discussions that will lead to the selection of a preferred IWQMS. Load allocations will be developed that reflect the load reductions anticipated through implementation of the preferred IWQMS. Figure 2-1 provides a general summary of the desired results from TMDL Phase 1 and 2 efforts.

The current pollutant loads affecting Lake Tahoe are summarized in Table 1-1. To achieve 29.7 m of clarity, loading of nitrogen, phosphorus & fine sediment to Lake Tahoe must be reduced by 30 to 40 percent.	**TMDL Phase 1 Results**
The selected IWQMS estimates these reductions can be found from the following sources: ___ (#) tons nitrogen, phosphorus & fines per stream channel ___ (#) tons nitrogen, phosphorus & fines per forest upland ___ (#) tons nitrogen, phosphorus & fines per urban upland ___ (#) tons nitrogen, phosphorus & fines per groundwater ___ (#) tons nitrogen, phosphorus & fines per atmospheric	**TMDL Phase 2 Results from the Selected IWQMS**
The SCGs recommend the following pollutant control options (PCOs) to achieve these reductions: Stream Channel Erosion __ (PCO #1) by __ (lbs. load reduction estimate, range or low/med/high) __ (PCO #2) by __ (lbs. load reduction estimate, range or low/med/high) Forest Uplands __ (PCO #3) by __ (lbs. load reduction estimate, range or low/med/high) etc…	**TMDL Phase 2 Results from SCGs**

Figure 1-1. Summary of expected results from TMDL Phases 1 & 2 describing pollutant load reduction requirements, load reduction estimates by source category, and recommended PCOs.

1.3. SCGs and Source Category Review Groups

The SCGs will focus on producing technical products that will support the extrapolation to Lake Tahoe Basin-wide load reduction potential and the development of IWQMS alternatives. Each SCG will include a group lead that will coordinate the technical investigations and overall staffing of the group and will be responsible for the products and findings of the SCG. The SCG Leads have been selected for their subject matter expertise, ability to deliver complex technical documents in a timely manner, and ability to coordinate with related investigations. The SCG Lead will define the specific process for evaluating PCOs for his/her source category. Each SCG will assemble a group of expert contributors, who will be selected based on their subject matter expertise, either at the national level or specific to the Lake Tahoe Basin. Contributors will provide technical input and analysis.

Each SCG has identified a number of resource managers and technical experts to review and provide input to the plans and products they will produce. Through written comments and verbal feedback the Source Category Review Group members will be asked to provide Lake Tahoe and agency-specific input related to this Work Plan and the results of PCOs analyzed. The Review Group members will also provide an important communication function, informing their organizations of SCG plans and initial SCG findings. The expected membership for each Review Group is included in the SCG specific chapters (Chapters 3 through 6).

Descriptions of the SCG membership and notes on their qualifications are included in the SCG specific chapters. The chapters also include the membership and agency representation of the Review Groups.

1.4. Source Category Integration Committee and Project Team

Review and cross-SCG coordination will be provided by a Source Category Integration Committee (SCIC) and the Tetra Tech Project Team (Project Team). The SCIC includes agency staff from Lahontan, NDEP and TRPA, a Pathway 2007 Steering Team Representative and a Science Advisor involved with the long-term TMDL development and implementation of water quality control projects in the Lake Tahoe Basin. The SCIC will:

- Maintain consistency between SCGs to ensure the products and reports from each group are comparable and useful for cross-source category pollutant reduction estimation
- Assure that the overall load reductions needed to attain the TMDL will be achieved from the cross-category analysis
- Assure that an adequate range of PCOs are evaluated
- Agree on evaluation parameters relevant to all source categories
- Provide guidance regarding communications and interactions with the Pathway Steering Team and Forum and other stakeholders

The Project Team will coordinate the day-to-day activities across the SCGs and will work with SCGs to assist in Lake Tahoe Basin-wide extrapolation and cross-category information exchange. The Project Team will assist in the development of the IWQMS alternatives, recommend load reduction allocations, and create a system to track pollutant load reduction credits generated during the implementation phase of the TMDL.

1.5. Pathway Forum & Stakeholder Engagement

The Pathway Forum exists to incorporate diverse public perspectives into the Pathway process. The Pathway Forum has provided recommendations regarding policies and PCOs of interest. In the spring of 2007 the Forum will review the results of the SCG analyses and in the summer of 2007 will be actively engaged in discussions regarding the selection of a preferred IWQMS. Lahontan TMDL staff will also conduct additional outreach through presentations, updates, and discussions at meetings of implementing agencies and specific constituency groups.

1.6. Products

Each SCG will produce a Load Reduction Matrix Analysis Report (LRMAR) with a summary Load Reduction Matrix (LRM) spreadsheet. The LRM and LRMAR for each SCG will document the results of the investigation of PCOs and findings of the overall source category load reduction potential. The LRM & LRMAR will include:

- Complete list of potential PCOs
- Load reduction potential estimates or evaluations for PCOs
- Documentation of methods used to develop load reduction estimates
- Recommended packages of PCOs to be applied in different physical and hydrologic settings

- Development of information required to extrapolate site- and subwatershed-scale evaluations to Lake Tahoe Basin-wide load reduction estimations
- Estimation of the overall load reduction potential for the source category
- Descriptions of methods and resources required to further refine load reduction estimates and evaluate difficult-to-quantify PCOs through the management system

Using the information in the LRM the SCIC will develop various IWQMS alternatives that will demonstrate different approaches to reach the pollutant load reduction targets required to meet the Lake Clarity TMDL.

1.7. Schedule

The SCGs initiated work in the late summer of 2006 and plan to complete detailed analyses by May 2007. From May through July of 2007 SCG members will assist the Project Team and SCIC by providing input related to development of IWQMS alternatives. Figure 1-2 provides an overview of the products, public input, and technical review points related to the SCGs.

Objective	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08
SCG Work Plan Development & Identification of PCOs		✔	●													
Complete Detailed PCO Analyses & Overall Source Category Load Reduction Potential							●									
Develop Draft LRM & LRMAR Documentation							X	✔	●							
Develop IWQMS Alternatives										✔	●	●				
Develop Preferred IWQMS											●	●	●			
Develop Load Allocations																●

X	Deliverable
✔	Review Group Interaction
●	Pathway Forum Input
	Primary SCG Role
	Advisory SCG Role
	Minimal SCG Role

Figure 1-2. SCG deliverables timeline showing points of input for Pathway Forum and Source Category Review Groups.

2. General Approach

The SCGs have been convened to assemble professional expertise related to each of the major sources of pollutants entering Lake Tahoe. While each SCG will tailor their approach to most effectively investigate their source category, they will all evaluate the same pollutants and produce comparable results. This chapter outlines the general approach and steps that the SCGs and SCIC will follow. Chapters 3 through 6 describe in detail the specific approach and Work Plan for each SCG. This general approach and the SCG specific Work Plans are subject to change as a result of input from reviewers and necessary adjustments discovered when attempting to complete these investigations.

Figure 2-1 provides an overview of the four step process that will result in the development of IWQMS alternatives. Step 1 involves the SCGs characterizing PCOs that may applied to reduce pollutant loading within the Lake Tahoe Basin. In Step 2 combinations of PCOs will be analyzed for their effectiveness at reducing pollutant loads in representative settings. These representative settings will include land uses, soils, slopes and other characteristics commonly found within the Lake Tahoe Basin. Each setting will be analyzed for tiers of treatment options to provide an understanding of the range of pollutant load reductions and associated costs resulting from implementation of different combinations of PCOs. The findings from this step will be summarized in a LRM.

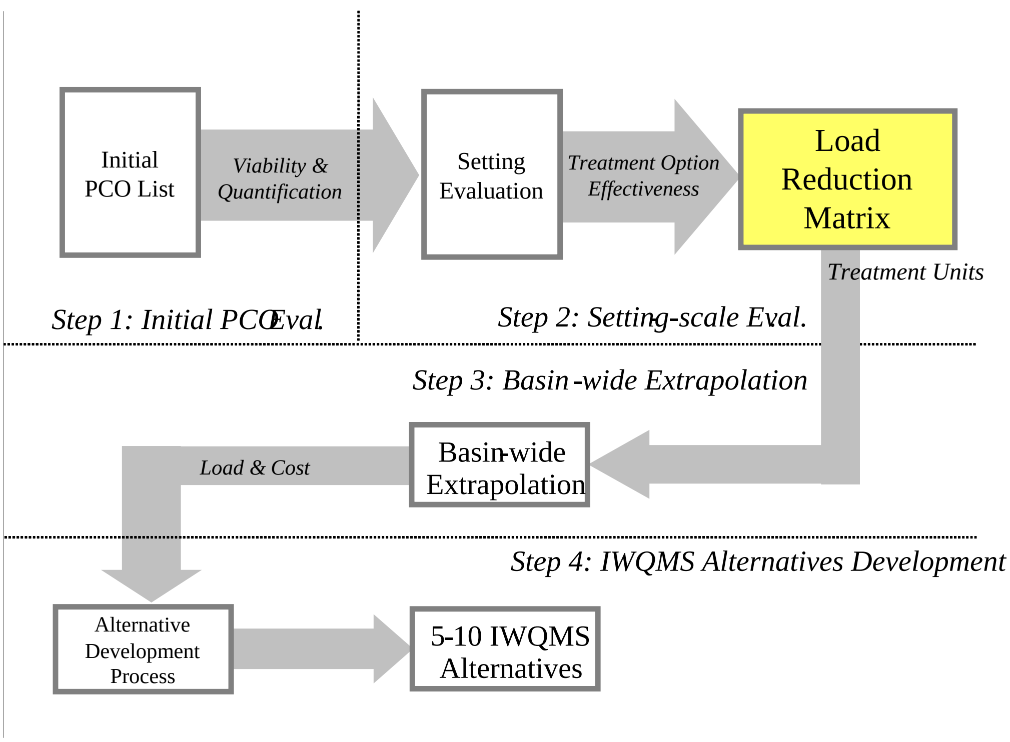


Figure 2-1. Diagram of IWQMS development process.

In Step 3 the setting level evaluations in the LRM will be used as the basis for extrapolation to the Basin-wide scale. The Watershed Model will be used as the extrapolation tool for the Urban Upland, Forest Upland and Groundwater SCGs. The Atmospheric Deposition SCG will develop use a spreadsheet tool to extrapolate potential load reductions. The Stream Channel Erosion SCG will sum estimated pollutant loads from the three streams analyzed. Graduated levels of adoption, representing different degrees of implementation, will be analyzed for each source category. Two examples of level of adoption include 25 percent of urban uplands treated and 50 percent of urban uplands treated.

In Step 4 the SCIC will use the information generated from the Basin-wide extrapolation to create a set of IQWMS alternatives that meet the established TMDL target loads. The IWQMS alternative development process will analyze combinations of treatment options and levels of adoption and will include related information including cost. Each IWQMS alternative will be run through the linked Watershed and Clarity Models for comparison with the existing baseline response and to confirm that they will result in TMDL attainment.

2.1. Pollutant Definitions and Species of Concern

The SCGs represent expertise in the fields of geomorphology, atmospheric science, groundwater processes, forest restoration and engineering hydrology. Each of these fields has unique methods for measuring and reporting pollutants of concern. For instance, atmospheric scientists report particles of 30 microns and less, while geomorphologists report particles of 63 microns and less.

Each SCG will report findings according to the available data and standard practice within their discipline. They will also capture any available data directly related to the following species of concern that are used in the Lake Clarity Model:

- Nitrate
- Ammonium
- Organic Nitrogen (as particulate and dissolved separately or combined)
- Total Phosphorous
- Soluble Reactive Phosphorous
- Inorganic particles $<20\ \mu m$

While the SCGs should provide any information that may assist with the estimation of these species of concern from reported data, the SCIC and Lake Clarity Modelers will develop relationships to translate to these species when necessary.

2.2. Step 1: Initial PCO Evaluation

Each SCG will first compile a list of potential PCOs based on professional experience, local knowledge, and input from the SCIC, Pathway Technical Working Groups, Pathway Forum, and others. From this comprehensive list of PCOs the SCGs will perform an initial screening based on ability to quantify the load reduction and expected effectiveness of the PCO within the Lake Tahoe Basin. This initial screening will focus investigations on PCOs that are expected to produce broad scale results and can be quantified well enough to be used in calculations for the IWQMS. The SCGs have already completed much of this step and their initial findings are presented for review in the SCG specific chapters of this Work Plan.

2.3. Step 2: Setting-Level Evaluations

The SCGs will provide the engineering, policy and local experience needed to use existing information to make calculated and well informed professional estimates of load reductions and costs. These estimates will be developed for representative settings that will be related to land use and transect classifications consistent with those used by Pathway 2007. All calculations and methods will be documented in the LRMAR and summarized in the LRM. The results of this step will enable Basin-wide extrapolation of load reductions in Step 3.

Pathway Transects

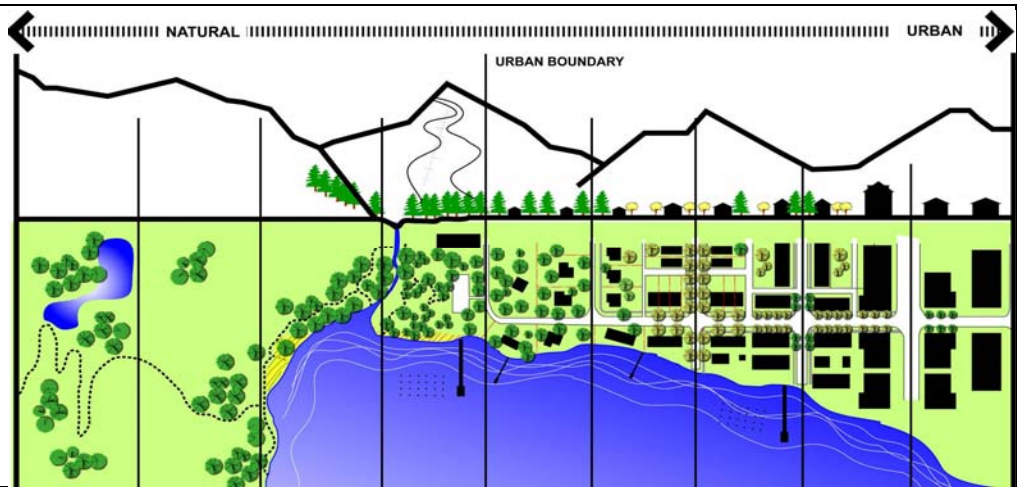
The Pathway 2007 transect classification system is a conceptual tool to describe the combinations of land uses that are found within the Lake Tahoe Basin. They present a mix of development type and density that can help planners and investigators understand the types of treatment options that will be used in different areas. Figure 2-2 shows an unpublished draft visual depiction and description of the nine transect classifications spanning a range of development from wilderness to urban core (provided by personal communication from Pathway 2007 management). A “special district” category is defined that will provide a unique definition of uncommon intersections between urban and conservation land uses. Using these transect classifications will support coordination with regional planners and facilitate the integration of SCGs findings into the overall Pathway planning effort.

Definition of Settings

Each SCG will categorize the physical characteristics of the Lake Tahoe Basin into a number of representative settings. Each setting will include reference to a transect classification and will define additional parameters such as level of development, slope, and soil type identified by the SCGs. Defining applicable settings will enable the use of geographic information system (GIS) tools to determine areas of the Lake Tahoe Basin where different types or combinations of PCOs may be appropriate. The number of settings will be selected to ensure that all treatable areas of the Lake Tahoe Basin are included, so there are no overlapping settings and such that a manageable number of setting-PCO combinations are created.

Treatment Tiers

SCGs will combine PCOs into treatment options that provide differing treatment levels for each setting. The treatment options will be designed to show a broad rage of effort and effectiveness. A “high tier” treatment option may include the most effective combinations of PCOs that are available, the most optimistic assumptions of setting-scale implemetability, and the most favorable literature values. A “low tier” treatment option may represent a “business as usual” approach that includes current practices and low literature values for effectiveness. SCGs are encouraged to define a “mid tier” that would represent an enhanced implementation of current practices. Each SCG will provide an explanation of their individual definition of each tier in their LRMAR.



Potential Transects Classifications	Wilderness	Roadless	General Conservation	Developed Recreation	Suburban LDR	General Urban HDR	Urban Center Mix-Use	Urban Core Town Center Mix-Use	Special District
Existing TRPA Land Use Classifications	Conservation			Recreation	Residential		Commercial/Public Service/Tourist		
Example Plan Area Statements/CPs	Desolation	Truckee Marsh	East Shore	Camp Richardson /Heavenly Ski Resort	Montgomery Estates	Sierra Tract/Bijou Al Tahoe	Meyers - Round Hill - Homewood CPs	Stateline - Tahoe City - Tahoe Valley CPs	CSLT Industrial/Kings Beach Industrial CP Areas
Land Use Strategies	No Development and Minimal Resource Management and Infrastructure	No Development or Infrastructure but Resource Management	Minimal developed facilities Accessible via Transit and Bicycle connections	Developed Recreation Uses Accessible via Transit and Bicycle Connections	Single-Family Zones with access to Transit, Pedestrian, and Bicycle Connections	Single-Family, Multi-Family Zones with access to Transit, Pedestrian, and Bicycle Connections	Smart Growth Principles: Walkable Community Centers, Commercial and Residential Mix-Uses, High Density, Public Amenities, Transit Centers, Pedestrian Connections Community Plans		Industrial and Public Service Special Design
	NA					Transit Oriented Design			NA
	Non Urban Areas			Urban Areas					
Land Uses/Density	Dispersed Recreation	Dispersed Recreation and Resource Management	Dispersed and Limited Developed Recreation Resource Management H&S and Linear PS	Developed Recreation Summer Homes Recreational Based Commercial	Residential SFD 1-8 units/ac. Urban Recreation & Resource Management	8-15 units/ac. Local Serving Commercial Urban Recreation & Resource Management	Mixed Use Density 8-15 Res. 8-40 Tourist Commercial Urban Recreation & Resource Management	Mixed Use Density TBD and All Non-Industrial Commercial Urban Recreation & Resource Management	Industrial and Public Service
Land Coverage	Minimal less than 1%	Minimal	Bailey	Bailey or 20-35% on Non Sensitive lands with Soil Conservation Plan	Bailey or 20-35% on Non Sensitive lands with Soil Conservation Plan	Bailey or 35-50% on Non Sensitive lands with Soil Conservation Plan	Bailey or 40-60% on Non Sensitive lands with Soil Conservation Plan	Bailey or 50-75% on Non Sensitive lands with Soil Conservation Plan	Bailey or 20-35% on Non Sensitive lands with Soil Conservation Plan

Figure 2-2. Graphical depiction of the nine transect types defined by Pathway 2007, providing the basic classification used to determine settings.

Common Evaluation Parameters

While each SCG will have source-specific information needs, methods, and parameters, the following common parameters will be evaluated in as consistent a manner as possible. These common evaluation parameters will allow reasonable comparison of pollutant treatment options between the SCGs. Discussion with the SCG Group Leads may refine these suggested parameters to better suit existing methods. These comparisons will become particularly important when the SCIC and Project Team create the IWQMS alternatives.

Load Reduction Effectiveness

Developing load reduction estimations will be the primary focus of the SCG analyses. Each SCG discusses their method for estimating load reductions in the SCG specific chapters that follow. All SCGs, with the potential exception of the Stream Channel Erosion SCG, will first estimate load reduction effectiveness resulting from different PCOs or treatment options in different settings. The Urban/ Groundwater and Forest Upland SCGs will populate an LRM tailored to the input needs of the existing Loading Simulation Program C++ (LSPC) watershed model that will be used in Step 3 to extrapolate SCG estimates Basin-wide. The LRM in Figure 2-1 shows an example of the expected LRM for these groups. The key input needed by the LSPC model is the load reduction effectiveness of a treatment option. This effectiveness should be expressed in different ways for flow, sediment, or nutrients. For flow, effectiveness should be expressed by in/acre of runoff infiltrated and/or detained. For sediment, phosphorous, or nitrogen, effectiveness can be expressed by effluent concentration for flow- or volume-based controls and by percent reduction for direct source controls.

Cost

Cost will be an important consideration in the development of overall IWQMS alternatives. Costs will include estimates of all known expenses associated with each treatment option analyzed for a particular setting. Estimates of costs will be sourced from:

- Data from public projects in Lake Tahoe
- Data from outside of the Lake Tahoe Basin for PCO applications
- Projected costs for advanced methods

Assumptions and relevant notes for each source category will be captured in the LRMAR. Evaluation should discuss costs associated with PCOs and treatment options that require institutional change, such as formation of a maintenance district or change in agency policies. Specific cost calculations will be defined through discussion with SCG Leads. The expected cost information includes:

- **Capital Investment Costs** that include the total cost to plan, design, and construct (or initiate) a PCO or treatment option for a particular setting. This calculation may include a capital recovery factor that will account for opportunity costs of investment when appropriate. As part of the capital cost reporting, SCGs will provide the expected life of the PCO or treatment option.

- **Average Annual Operations and Maintenance (O&M) Costs** that include all requirements to operate (electricity, personnel, materials, etc.) and maintain effectiveness (vactoring, re-planting, inspections, policy enforcement, etc.) of the PCOs at the efficiency used in load reduction calculations for the expected life of the project.

- **Cost per Unit Effort** is the total cost for the treatment option at the setting-level divided by the characteristic variable that describes how much of the treatment option was produced or implemented. In the Urban Upland source category, the unit effort will most likely be determined by acres treated; in the Stream Channel Erosion source category, the unit effort may be the linear feet of channel treated. The relevant unit of effort will be defined for each PCO or treatment option. This information will be used to calculate a total, bulk cost of the treatment option when it is extrapolated to the Lake Tahoe Basin-wide scale.

Other Resource Effects

Any significant impacts or benefits to other resources that are likely to result if a particular PCO or treatment option is implemented will be documented in the LRMAR. If a treatment option is analyzed that relies on armoring large portions of stream systems, a discussion of potential impacts to habitat would be included. Likewise, potential habitat benefits from wetland restoration would also be noted.

Uncertainty

The calculations and estimates of load reductions will include uncertainty due to the current limits of understanding associated with pollutant loading. To address uncertainty, the SCGs will take a qualitative approach that will consist of noting the types of uncertainty associated with their analysis for each setting and treatment tier.

Example LRM

The information collected and estimates provided by the SCGs will be captured in the LRM. Figure 2-1 shows a conceptual LRM that summarizes setting-level estimates for common evaluation parameters. The contents of the LRM will vary by source category and will be defined by the input needs for the Basin-wide extrapolation method for each group. The formulation of the LRM is described in more detail for each SCG in the following chapters.

Sources	Effectiveness	Cost	Contstraints	Etc.	Estimated Load Reduction
STORMWATER- URBAN					
Infiltration	4	$	2		xx kg/yr
Wetland Treatment	7	$$	7		xx kg/yr
Source Control	6	$	1		xx kg/yr
Chemical Enhancement	9	$$$	8		xx kg/yr
ATMOSPHERIC					
Vehicle Emission Control	4	$$	4		xx kg/yr
Wood Stove Management	5	$$	3		xx kg/yr
Out-of-Basin Source Control	2	$$$	9		xx kg/yr
Dust Management	7	$	2		xx kg/yr
STREAM CHANNELS					
Stream Restoration	7	$$$	5		xx kg/yr
Bank Stabilization	7	$$	3		xx kg/yr
Hydrological Controls	5	$	2		xx kg/yr
GROUND WATER					
Fertilizer Management	3	$$	7		xx kg/yr
Source Control	8	$	2		xx kg/yr
STORMWATER - FORESTED AREAS					
Road Management	6	$$$	6		xx kg/yr
Trail Management	5	$$	5		xx kg/yr
Fire Restoration	7	$$	4		xx kg/yr
				Total Possible Load Reduction	**xx kg/yr**

Figure 2-3. Conceptual representation of the LRM that will summarize common evaluation parameters determined by the SCGs during setting-level evaluations.

2.4. Step 3: Basin-Wide Load Reduction Extrapolation

The information contained within the LRM will be used as the basis for a Basin-wide extrapolation of overall load reduction from each source category. Several different combinations of treatment options and levels of adoption will be analyzed to provide a range of potential load reductions possible from each source category. Each Basin-wide analysis will include a discussion or estimation of cost and other factors, such as uncertainty and potential positive or negative effects on other resources. The specific modeling and mathematical techniques for performing the Basin-wide extrapolation are described for each source category in Chapters 3 through 6.

2.5. Step 4: IWQMS Alternatives Development

The load reduction and cost information developed in the Basin-wide extrapolation will be used to formulate several IWQMS alternatives. The alternatives development process will be initiated by the SCIC and Project Team analyzing different combinations of treatment options and levels of adoption for each source category that, cumulatively, are expected to meet the load reduction target. The Watershed and Lake Clarity Models will be used to determine the expected lake clarity from the different combinations of load reductions. Any combination that results in meeting clarity goals will be an IWQMS alternative.

IWQMS alternatives will be developed that emphasize reductions from different source categories as well as a variety of other factors that will be defined through discussions with stakeholders and technical reviewers. The IWQMS alternatives will be the focal point for discussions with stakeholders that will result in the selection of a single IWQMS.

3. Atmospheric Deposition SCG Specifics

Atmospheric deposition contributes roughly half of the nitrogen load to Lake Tahoe. In addition, portions of the other pollutants of concern are also deposited via this source. Recent studies indicate that the pollutants most closely connected to the decline in Lake Tahoe's clarity largely originate from within the Lake Tahoe Air Basin with some unquantified portion from sources outside the Basin.

PCOs to reduce fine particulate and nutrients emissions have been identified and will be analyzed for different land uses and settings within the Lake Tahoe Basin. The Basin-wide load reduction extrapolation will use load reduction and cost estimates based on road area and other measures of effort developed through the setting level analysis. A spreadsheet analysis will be used to estimate Basin-wide load reductions from different treatment options and levels of adoption to understand both maximum and more feasible potential load reductions from direct deposition of pollutants on the lake surface.

3.1. Source Discussion

The SCG Lead identified major pollutant sources from the California Air Resources Board (CARB) emissions inventory for the Lake Tahoe Air Basin as well as CARB's findings from the 2003 Lake Tahoe Atmospheric Deposition Study. The SCG Lead used these sources to select a large number of PCOs for the major in-Basin sources of nitrogen, phosphorus, and fine sediments. To a first approximation, fine sediments of atmospheric origin can be equated to fugitive dust of geological origin in the total suspended particulate (TSP) size range (i.e., particles with diameters less than ~ 30 μm).

Although there are problems with CARB's emission inventory for the California portion of the Lake Tahoe Air Basin (see Appendix A for a list of these problems) that render it inaccurate on an absolute basis, the inventory identifies the major sources of the three pollutants of interest. One of the first tasks for the Atmospheric Deposition SCG for the next phase of this project is to work with CARB to address the uncertainties of the current emission inventory. Allan Gertler, an SCG member, will also provide locally based information that may not have been integrated into the CARB inventory.

The major atmospheric sources of fine sediment, phosphorus, and nitrogen generated from local sources within the Lake Tahoe Air Basin are the following.

- **Paved Roads –** Extrapolating CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin to the entire Basin indicates that paved road dust accounts for about 41 percent of the fugitive soil dust emissions (with 90 percent of these emissions from major and local streets and the balance from freeways and collector streets), 44 percent to 61 percent of the phosphorus emissions (depending on which paved road dust source profiles are used), and none of the NO_x emissions.

- **Unpaved Roads –** Extrapolating CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin to the entire Basin indicates that unpaved road dust accounts for about 43 percent of the fugitive soil dust emissions (with 61 percent of these emissions from Bureau of

Land Management (BLM) roads, 36 percent from city/county roads, and the balance from USFS/State Park roads and farm roads), 31 percent of the phosphorus emissions, and none of the NO_x emissions.

- **Construction/Demolition –** Extrapolating CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin to the entire Basin indicates that construction and demolition accounts for about 14 percent of the fugitive soil dust emissions (with 43 percent of these emissions from residential construction, 31 percent from road construction, 13 percent from commercial construction, 9 percent from institutional construction, and 5 percent from industrial construction), about 14 percent of the phosphorus emissions, and none of the NO_x emissions.

- **Mobile Sources** – This category includes both on-road vehicles traveling on paved and unpaved roads as well as other modes of transportation (aircraft, watercraft) and off-road sources (primarily construction equipment). CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin indicates that mobile source exhaust emissions accounted for none of the fugitive soil dust or phosphorus emissions, and about 90 percent of the NO_x emissions. The SCG will evaluate the impact of watercraft exhaust emissions that are emitted below the waterline directly into the lake.

- **Residential Wood Combustion (RWC)** - CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin indicates that RWC accounted for none of the fugitive soil dust or phosphorus emissions and about 6 percent of the NO_x emissions. This figure will be checked with other investigators as it has been questioned by the SCIC.

3.2. Initial Evaluation of PCOs

The SCG Lead has made an initial assessment of the PCOs for atmospheric pollutant sources. Table 3-1 divides the sources into sub-categories, lists PCOs for each sub-category, notes whether load reductions are quantifiable on a Basin-wide scale, and provides a qualitative assessment of their viability.

Load Reduction Quantification

Each PCO has been qualitatively categorized according to the SCG Lead's ability to quantify its potential load reduction. If the load reduction for each PCO is quantifiable utilizing information that is currently available they are labeled "yes" under the column titled "Quantifiable Load Reduction." There are many PCOs for which there is insufficient information to quantify their load reduction potential. However, it may be possible to provide a "ballpark" estimate of the PCO's load reduction potential using various assumptions and best professional judgment. The PCOs that fall in to this category are identified with the label "maybe" under the column titled "Quantifiable Load Reduction." During the remainder of this project, the SCG will identify and collect the additional information that is needed to quantify the load reduction potential of these PCOs.

Viability

Each of the PCOs has also been evaluated for viability and assigned a viability rating of High, Medium, or Low. At this early stage the ratings are simple subjective estimates based on the SCG Lead's best professional judgment regarding the technical feasibility, applicability, and various constraints or obstacles (e.g., acceptability, economic, regulatory) to implementation. All of the PCOs identified in Table 3-1 are technically feasible, having been employed previously in other areas of the country. Furthermore, all of these PCOs are directly applicable for the Lake Tahoe Air Basin and there are no obvious regulatory constraints to implementing them. PCOs were assigned a high viability rating if there are no impediments to implementation. PCOs were assigned a medium viability rating if there was a perceived serious constraint to implementation and a low viability rating if there are known serious constraints to implementation. Additional time and effort is needed to finalize the viability rating of each PCO. The SCG Lead will work with the Transportation Working Group to identify which PCOs associated with on-road and off-road mobile sources as well as PCOs for reducing resuspended paved and unpaved road dust emissions are viable from the standpoint of the public's acceptance. For example, many of the PCOs for mobile sources identified in Table 3-1 involve providing incentives to individuals to modify their habits. These incentive-based programs have worked successfully in other parts of the country and there is no reason to believe that they would not be successful in the Lake Tahoe Air Basin. The SCG Lead will work with the TRPA and the SCIC to address the economic viability of each PCO.

Initial assessments of both viability and quantification potential are subjective and should not automatically rule out further assessment of any of the PCOs listed in Table 3-1.

Table 3-1. Assessment of PCOs for Atmospheric Sources of Fine Sediments and Nutrients

Source Category	Potential Control Option	Quantifiable Load Reduction	Viability
Paved Roads	1a. Deicers instead of cinders and sand	Yes	High
	1b. Designated sites for snow removed from road	Maybe	High
	1c. Vegetation/barriers	Maybe	High
	1d. Pave shoulders	Yes	Medium
	1e. Clean gutters and curbs	Maybe	High
	1f. Move traffic to roads further inland from lake	Maybe	Low
	1g. Tarps for haul trucks	Maybe	High
	1h. PM10-efficient vacuum units	Yes	High
	1i. Replace sweepers with PM10-efficient vacuum units	Yes	High
	1j. Cleanup erosion deposits/spills within 24 hours of discovery	Maybe	High
	1k. Remove abrasive material from road ASAP	Maybe	High
Unpaved Roads	2a. Maximum speed limit of 25 mph	Maybe	High
	2b. Limit weight and/or number of vehicles	Maybe	High
	2c. Pave unpaved roads/parking lots	Yes	High
	2d. Apply gravel or slag	Yes	High
	2e. Pipe-grid system or gravel bed to control trackout	Yes	High
	2f. Plant a vegetative cover	Maybe	High
	2g. Road closures	Yes	High
	2h. Water industrial unpaved roads	Yes	High
	2i. Chemical dust suppressant	Yes	High
	2j. Vegetation/Barriers	Maybe	High
	2k. Prohibit new roads where soil instability is an issue	Maybe	High
	2l. Move traffic to roads further inland from lake	Maybe	Low
Construction/Demo	3a. Water disturbed surfaces at regular intervals	Yes	High
	3b. Chemical dust suppressants	Yes	High
	3c. Barriers around the site for soil dust sequestration	Maybe	High

	3d. Ban demolition/grading activities if wind >25 mph	Maybe	High
	3e. Require minimum soil moisture of 12% for earthmoving	Maybe	High
	3f. Limit on-site vehicle speeds to 15 mph	Maybe	High
	3g. Prohibit new roads where soil instability is an issue	Maybe	High
	3h. Pipe-grid system or gravel bed to control trackout)	Yes	High
	3i. Pave construction access road	Yes	High
	3j. Clean access roads frequently	Maybe	High
Farming Ops	4a. Equipment modifications	Maybe	Medium
	4b. Process modifications	Maybe	High
	4c. Limited activity during high winds	Maybe	High
RWC	5a. Ban new wood burning stoves/fireplaces	Yes	Medium
	5b. Replace non-approved stoves	Maybe	Medium
	5c. Ban RWC during periods with poor atmospheric dispersion	Maybe	High
	5d. Limit wood to hardwoods or pellets with low moisture	Maybe	High
	5e. Weatherize residences heated by wood stoves	Maybe	Medium
Managed Waste Burning	6a. Limit burning to periods with high atmospheric dispersion	Maybe	High
	6b. Ban all open burning	Yes	High
Mobile	7a. Trolley or elevated tram service	Maybe	Low
	7b. Ski shuttle services	Maybe	Medium
	7c. Inter-city bus services for casino guests	Maybe	Medium
	7d. Facilitate non-motorized transportation	Maybe	Medium
	7e. Incentives for the use of bike lanes	Maybe	Medium
	7f. Create a pedestrian friendly environment	Maybe	Medium
	7g. Incentives for alternative fuel use	Maybe	Low
	7h. Mass transit incentives	Maybe	Medium
	7i. Employer-based trip reduction incentives	Maybe	Medium
	7j. Incentives for alternate driving days	Maybe	Low
	7k. Incentives for vanpools for commuters	Maybe	Medium
	7l. Incentives for ferry travel to reduce road travel	Maybe	Low
	7m. Synchronize traffic signals to minimize idling time	Maybe	Medium
	7n. Ban boating during late evening/early morning hours	Maybe	Low
	7o. Annual Smog Check for cars >4 years with no exemptions	Maybe	Medium
	7p. Reduce commercial shipping activities	Maybe	Low
	7q. Limit travel during late evening/early morning hours	Maybe	Low
	7r. Particulate filters for diesel trucks and buses	Maybe	Low
	7s. Particulate filters/ oxidation catalysts for diesel boats	Maybe	Low
	7t. Retrofit vehicles/boats with cleaner engines	Maybe	Low
	7u. Inspection program for off-road equipment	Maybe	Medium
	7v. Road-side inspection of heavy duty diesel trucks/buses	Maybe	Medium
	7w. Incentives to retire older vehicles	Maybe	Medium
	7x. Incentives for all Basin residents to purchase CA fuel	Maybe	Low

3.3. Setting-Level Evaluation Approach

Currently, there are no data available to develop load reduction estimates for atmospheric sources of pollutants for specific areas of the Lake Tahoe Air Basin. Thus, the SCG Lead proposes strictly Basin-wide estimates of pollutant control strategies for the pollutants of interest. Since many of the different source categories emit two, or in some cases three, of the three pollutants of interest, each PCO has the potential to reduce the emissions of multiple pollutants. For example, reducing the number of vehicles traveling on a road to control NO_x emissions from vehicle tailpipes will simultaneously reduce the emissions of re-suspended road dust. Before developing load reduction estimates for atmospheric sources of pollutants, the SCG will investigate which PCOs were in use at the time the baseline loading measurements were performed. The SCG Lead will work with the other SCG Leads to ensure that the impact of implementing a PCO to reduce atmospheric pollutants is addressed appropriately by the other SCGs.

Load Reduction

A technical approach for estimating the load reduction for the entire lake for each pollutant of interest is presented in this section.

For inert species such as fine sediments and phosphorus linked to fine sediments, the load reduction should be linear with emission reduction of these pollutants. Thus, the maximum load reduction potential for each control measure is equal to the percentage contribution from each source category (e.g., paved roads, mobile sources, etc.) to the total pollutant load for the pollutant of interest multiplied by the highest published control efficiency for that control measure. For nitrogen species the load reduction is most probably not linear with emissions reduction. For example, the formation of nitric acid in the atmosphere from oxides of nitrogen originating from any combustion source is non-linear, neither is the subsequent reaction of nitric acid with ammonia in the atmosphere to form secondary ammonium nitrate particles. However, for qualitative purposes and to develop initial estimates, the SCG will assume a linear relationship between NO_x emissions and atmospheric deposition of nitrogen species to the lake.

Sample Calculation

The major sources of atmospheric deposition of fine sediments in the Lake Tahoe Air Basin in descending order of percent contribution to the TSP emissions are unpaved road dust (43 percent), paved road dust (41 percent), construction and demolition (14 percent), and farming operations (2 percent). For inert species such as soil dust, the fine sediment pollutant load to the lake will be directly proportional to the fugitive soil dust emissions for the air basin. Thus, 41% of the annual fine sediment pollutant load to the lake of 1,400 metric tons per year (MT/year), namely 574 MT/year, is estimated to be due to resuspended paved road dust. The maximum load reduction potential from biweekly vacuum sweeping of all paved roads in the Lake Tahoe Basin is calculated by multiplying the annual fine sediment load to the lake due to resuspended paved road dust (574 MT/year) by the highest published control efficiency for this control measure, namely 35 percent. The maximum fine sediment load reduction for this control measure is calculated to be 201 MT/year. There will be a simultaneous reduction in phosphorus load from implementing this PCO. Based on CARB's source profile data presented in Table A-4 of Appendix A, paved road dust contributes 44 percent of the total phosphorus emissions for the air basin. This translates into 44 percent of the 8 MT/year of the atmospheric source of phosphorus being deposited into the lake each year, namely 3.5 MT/year, originating from resuspended paved road dust. Thus, implementing a control measure for paved road dust with a control efficiency of 35 percent will reduce atmospheric phosphorus emissions by 35 percent, resulting in a maximum load reduction of atmospheric phosphorus of 1.2 MT/year.

Cost Effectiveness

Rather than presenting existing, less robust cost-effectiveness estimates, the SCG Lead proposes a step-wise methodology to calculate cost-effectiveness, as is presented below. The cost-effectiveness estimates for different control options should be based on current cost data and assumptions that are applicable to the specific situation. These estimates and assumptions will be captured in the LRMAR.

Step 1: Select a specific control measure for the fugitive dust source category of interest.

Step 2: Specify the following basic parameters required to calculate uncontrolled and controlled emissions for the specific source:
- (a) applicable emission factor equation
- (b) parameters used in the emission factor equation
- (c) source extent (activity level)
- (d) characteristics of the source
- (e) control measure implementation schedule (frequency, application rate)

Step 3: Calculate the annual uncontrolled emission rate as the product of the emission factor and the source extent (from Step 2).

Step 4: Determine the control efficiency for the selected control measure. This may involve either (a) using a published value, (b) calculating the control efficiency based on comparing the controlled emissions estimate derived from the applicable emission factor equation with the uncontrolled emissions estimate derived from the same emission factor equation, or (c) specifying the desired control efficiency which then will entail determining the appropriate level of control to achieve the desired control efficiency.

Step 5: Calculate the annual controlled emissions rate (i.e., the emissions remaining after control) as the product of the annual uncontrolled emission rate (from Step 3) multiplied by the percentage that uncontrolled emissions are reduced, as follows: Controlled emissions = Uncontrolled emissions x (1 – Control Efficiency).

Step 6: Calculate the reduction in emissions as the difference between the annual uncontrolled emission rate (from Step 3) and the annual controlled emission rate (from Step 5).

Step 7: Gather cost estimates for implementing the selected control measure for the following items:
- (a) annualized capital costs (total capital costs, lifetime of the control)
- (b) annual operating and maintenance costs that include overhead, enforcement, and compliance costs

Step 8: Calculate the annualized capital investment cost as the product of the annual capital cost and the capital recovery factor. The capital recovery factor is calculated as follows:

$$CRF = [\, i\,(1 + i\,)^{n}\,] / [(1 + i)^{n} - 1]$$

where, i = annual interest rate (fraction)
n = number of payment years

Step 9: Calculate the total annualized cost by combining the annualized capital investment cost (from Step 8) with annual operating and maintenance costs (from Step 7).

Step 10: Calculate the cost-effectiveness of the selected control measure by dividing the total annualized costs (from Step 9) by the emissions reduction. The emissions reduction is determined by subtracting the controlled emissions (from Step 5) from the uncontrolled emissions (from Step 3).

Load Reduction Uncertainty

The SCG will make a qualitative assessment of the uncertainty of the maximum load reduction potential estimates calculated for each PCO selected by the SCIC for further evaluation. This assessment will consist of assigning a ranking to the uncertainty associated with each maximum load reduction potential estimate. At this stage, the SCG Lead anticipates that the rankings will represent the following range of uncertainties:

- High uncertainty—estimates expected to be within an order of magnitude
- Medium uncertainty—estimates expected to be within ± 200 percent
- Low uncertainty—estimates expected to be within ± 50 percent

3.4. Basin-Wide Load Reduction Evaluation

The SCG Lead proposes to rank the PCOs for each pollutant of interest for each major source category based on two criteria—load reduction potential and cost-effectiveness. The SCG will utilize these results to recommend packages of PCOs to the SCIC. Based on the SCIC's feedback, the SCG will calculate the Lake Tahoe Basin-wide load reduction potential from implementing different treatment options (packages of PCOs) for atmospheric sources of fine sediments, nitrogen, and phosphorus. This proposed approach is somewhat different than other SCGs in that the treatment options are proposed for a Lake Tahoe Basin-wide scale as opposed to the setting-scale.

The investigation will only apply one PCO or treatment options to any fraction of the overall road surface to avoid double counting (e.g., paving all unpaved roads as well as applying gravel over all unpaved roads simultaneously). Lake Tahoe Basin-wide load reduction potential calculations may include implementation of one PCO for some fraction of the paved (or unpaved roads) in the Lake Tahoe Basin and a different PCO for another fraction of paved (or unpaved) roads. This is analogous to the different settings used by other SCGs.

In addition, implementing different PCO for different seasons will be considered. For example, switching from anti-skid materials to deicers for snow- and ice-covered paved roads during the winter months and biweekly street sweeping program with PM10-efficient vacuum units for the balance of the year could be considered.

High Tier Treatment Option

To estimate the maximum load reduction potential, the SCG will use the highest published control efficiency for that PCO. Furthermore, it will be assumed that the PCO is applied to all of the local sources of the pollutant of interest (i.e., 100 percent penetration of the PCO) and that the control efficiency of each PCO is sustainable from year to year. A sample calculation for estimating the maximum load reduction potential from implementing a package of PCOs simultaneously for the major source categories of fine sediments is presented below for illustrative purposes. Finally, the SCG will determine an appropriate methodology for estimating Lake Tahoe Basin-wide load reductions based on assumptions of less than 100 percent penetrations of PCOs (i.e., 75 percent, 50 percent and 25 percent penetration) and control efficiencies lower than the highest published values.

Sample Calculation

The major sources of atmospheric deposition of fine sediments in the Lake Tahoe Air Basin in descending order of percent contribution to the total TSP emissions are unpaved road dust (43 percent), paved road dust (41 percent), construction and demolition (14 percent), and farming operations (2 percent). For inert species such as soil dust, the fine sediment pollutant load to the lake will be directly proportional to the fugitive soil dust emissions for the air basin. Thus, the annual fine sediment pollutant load to the lake of 1,400 MT/year can be assigned to the following sources: 602 MT/year from resuspended unpaved road dust, 574 MT/year from resuspended paved road dust, 196 MT/year from resuspended soil dust from construction and demolition activities, and the balance of 28 MT/year from farming operations. The maximum load reduction potential from implementing the most cost-effective control measure for each of these four atmospheric source categories of fine sediments is calculated by summing the maximum load reduction potential for each control measure. In this example, it is assumed for illustrative purposes that the most cost-effective control measure for unpaved and paved roads each has a maximum control efficiency of 35 percent, the most cost-effective control measure for construction and demolition activities has a maximum control efficiency of 84 percent, and the most cost-effective control measure for farming operations has a maximum control efficiency of 50 percent. Therefore, the maximum load reduction potential for each source category is calculated to be 211 MT/year, 201 MT/year, 165 MT/year and 14 MT/year, respectively, resulting in a total maximum load reduction potential of 591 MT of fine sediments per year from implementing this package of PCOs. This reduction in fine sediment load will be accompanied by a simultaneous reduction in phosphorus.

These series of calculations will allow the SCG to develop a table of Basin-wide load reductions based on several combinations of PCOs and treatment options.

3.5. SCG and Review Group Membership and Expertise

Countess Environmental is leading the Atmospheric Deposition SCG. Dr. Richard Countess is principle of this small company and has over 30 years of experience working on air quality issues in the western United States. This experience includes extensive work with CARB, contributions to region-wide source inventories, and in-depth analysis of fugitive dust control costs. The qualifications of the SCG Contributors and Research Assistant are summarized in Table 3-2. The overall group qualifications include:

- Over 80 years of combined experience in air quality research, planning, and statistical analysis
- California and national level environmental policy expertise
- Lake Tahoe Basin emissions inventory expertise
- Recent analysis of fine particle resuspension of road dust

Table 3-2. Atmospheric SCG Members and Expertise

Person	Role	Affiliation	Expertise
Dr. Richard Countess	Lead	Countess Environmental	Nationally recognized fugitive dust expert with more than 30 years of experience. Recently developed handbook on atmospheric emissions and control measures for fugitive dust for the Western Regional Air Partnership.
Dr. Alan Gertler	Contributor	Desert Research Institute	Nationally recognized research scientist with more than 20 years of experience specializing in mobile source emissions.
Susan Countess	Contributor	Countess Environmental	Senior ASQ Quality Assurance Engineer with more than 25 year of experience performing statistical data analyses.

The Atmospheric Deposition Review Group brings significant local and regional expertise to help guide investigations and provide detailed review of work products. The suggested Review Group members are summarized in Table 3-3. Suggested members are being contacted to determine their availability and willingness to participate.

Table 3-3. Proposed Atmospheric Review Group Members and Key Information

Person	Perspective	Affiliation
Charles Emmet	Air quality regulations	TRPA, Pathway Air Quality Technical Working Group (TWG)
Karen Fink	Transportation planning	TRPA, Pathway Transportation TWG
Dr. Tom Cahill	Research and science	UC Davis
Jennifer Carr	Air quality regulations	NDEP
Nol Bonderson/staff	Municipal projects	Washoe County
Staff	Municipal projects	El Dorado or Placer County
Dave Roberts	TMDL	Tahoe TMDL Team, SCIC, Air Quality TWG Liaison
John Watson	Research and science	Desert Research Institute/Atmospheric Processes
Patrick Gaffney	Research and science	CARB/Emissions
Chatten Cowherd	Research and science	Midwest Research Institute/Control Measures

4. Urban Uplands/Groundwater SCG Specifics

The Urban Uplands and Groundwater SCG will estimate the pollutant load reductions associated with PCOs for urban stormwater runoff, including infiltration to groundwater, for typical settings in the Lake Tahoe Basin. Reduction of pollutant loads associated with stormwater is the focus of Lake Tahoe Basin regulations and programs, including major water quality improvement projects implemented by local governments and agencies. These projects typically combine many types of improvements intended to reduce pollutant loads, but their cumulative effects for reducing pollutant loading in stormwater runoff are currently not well quantified. In addition, potential loads to groundwater from infiltration of urban stormwater are not well quantified.

The Urban Uplands and Groundwater SCG will use a basic mass balance approach to analyze pollutant load reductions from implementation of combinations of PCOs in typical urban settings. The mass balance approach will allow the investigations to determine which pollutants eliminated from surface water flows enter the groundwater and which are effectively removed from the system. PCOs will be categorized as hydrologic source controls, pollutant generation source controls, and stormwater treatment. Setting scale pollutant load reduction estimates will be determined by various techniques guided by the framework used by the Pollutant Load Reduction Estimator – Spreadsheet for Tahoe Stormwater (PLRE-STS). Basin-wide extrapolation will be performed using the Watershed Model.

4.1. Source Discussion

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Current practices for water quality improvement and protection in the Lake Tahoe Basin include implementation of best management practices (BMPs) on private and public lands and in public rights-of-way. Water quality is affected by improvements constructed both at the parcel scale (generally private property BMPs) and at the scale of typical urban catchments (generally public projects associated with the Environmental Improvement Program [EIP]). In both cases, water quality improvement is based on application of combinations of various BMPs, and BMP selection is influenced by site characteristics. The performance of various combinations of BMPs in reducing stormwater loads is variable and difficult to estimate at the scale of typical urban settings and drainage catchments. Some urban stormwater BMPs infiltrate flows to groundwater, potentially rerouting a fraction of the pollutant loads to Lake Tahoe via this source.

The Urban Uplands and Groundwater SCG approach therefore must consider the effects of multiple BMPs implemented across a range of settings. This problem is complicated by relatively meager information on the performance of individual BMPs in the Lake Tahoe Basin and the interdependence of BMP performance when implemented in combination in project designs. Although the estimates will involve considerable uncertainty, the following best available sources will be used, to the extent practical, to develop estimates of individual and combined BMP performance:

- Tahoe-specific data and observations – empirical estimates
- Tahoe-specific data and observations – unit process-based estimates (physical and chemical)
- BMP and watershed monitoring data and modeling results from other geographic areas

A large number of both structural and non-structural BMPs are applicable to Lake Tahoe stormwater. To reduce the potential number to be considered, the SCG has grouped BMPs according function and process in reducing pollutant loads. Each of these groups is referred to as a PCO – note that there may be several variations on BMP design that fit in a single PCO.

The sources and PCOs affecting pollutant load delivery in the urban upland and groundwater source category are further organized into the following major load reduction functions—hydrologic source controls, pollutant generation source controls, and stormwater treatment. Within each of these major functional elements, several PCOs may be identified. Pollutant load reductions can be associated with each of these major elements and this organization is consistent with current Tahoe Basin practice (Preferred Design Approach and Formulating and Evaluating Alternatives process) for implementation of stormwater quality improvement projects in the Lake Tahoe Basin. The following summarizes the major load reduction functions:

- **Hydrologic Source Controls –** reduce runoff by retaining or providing for the processes of interception, infiltration, and evapotranspiration. Note that some hydrologic source controls for surface water may also reroute pollutant loads to groundwater.

- **Pollutant Generation Source Controls –** reduce the supply of pollutants by reducing the potential for pollutants of concern to be mobilized and transported. This includes sources that may be widely distributed in a catchment (e.g., land surface erosion, fertilizer applications, animal waste) and those that are more concentrated specific sources (e.g., gullies).

- **Stormwater Treatment –** remove pollutants after they have entered concentrated stormwater runoff flow paths. These treatment PCOs may or may not include treatment of flows infiltrated to groundwater as well as those discharged to surface waters.

4.2. Initial Evaluation of PCOs

The SCG has made an initial assessment of the PCOs for urban upland and groundwater sources. Table 4-1 lists the individual BMPs and associated PCOs applicable to the urban uplands and groundwater SCG, grouped by major functional element.

Load Reduction Quantification

Table 4-1 also provides a qualitative evaluation of whether it is feasible to quantitatively estimate load reduction from each PCO. Note that quantification of PCO effectiveness will require definition of the intensity of PCO application in the form of simple hydraulic or hydrologic design criteria, frequency of application, or other metrics. Some PCOs will not have sufficient information to accurately quantify their load reduction potential. However, it may be possible to provide a "ballpark" estimate of the load reduction potential for each approach using relative comparisons to other PCOs and best professional judgment (labeled as "maybe" in Table 4-1).

During the project, the SCG will identify and collect additional information needed to quantify the load reduction potential, to the extent feasible, of the listed PCOs. For the hydrologic and pollutant generation source control PCOs, these estimates will be provided on a land use basis, either in the form of modified median Event Mean Concentrations (EMCs) or percent reduction in loads. Treatment performance estimates will not be provided in this format because treatment PCOs typically apply to catchments of mixed land use. Load increases and load reductions to groundwater will be estimated separately and presented in a similar format. A few exceptions to the land use basis for estimating effectiveness for individual PCOs may exist. For example, animal waste or sewer exfiltration sources may not be quantifiably associated with the land use classes used for other PCOs and might best be estimated at a larger regional scale.

Viability

Table 4-1 also provides an initial evaluation of each PCO's viability for implementation in the Lake Tahoe Basin. Viability ratings are based on applicability to Tahoe Basin settings and climate, assumed short-term and long term effectiveness, and maintenance and institutional acceptability. At this early stage the ratings are subjective, based on the SCG Lead's experience. Additional time and effort will yield greater confidence in the ratings and additional input information.

Table 4-1. Initial Evaluation of PCOs for Urban Uplands and Groundwater

Source Category/ Treatment Option	Potential Control Option	BMP	Quantifiable Load Reduction	Viability
Hydrologic Source Controls	1. Redirection or separation of runoff	a. Berms	Maybe	Low
		b. Piping		
	2. Decrease amount of runoff generated	a. Hard coverage removal	Yes	High
		b. Soft coverage removal		
		d. Pervious pavement		
		e. Soil restoration		
	3. Decrease amount of runoff reaching catchment outlet	a. Routing impervious runoff to pervious area	Yes	High
		b. Perforated piping		
		c. Infiltration trenches		
	4. Private BMP implementation to detain and infiltrate runoff	a. Percolation trench	Yes	High
		b. Slotted drain		
		c. Drywell		
		d. Pervious pavement		
		e. Pre-fabricated infiltration system		
Pollutant Source Controls	1. O&M	a. Road abrasive application management	Maybe	Medium
		b. Street sweeping		
		c. Recovery of detained pollutants		
	2. Road shoulder stabilization	a. Curb and gutter	Maybe	High
		b. AC berm or AC swale		
		c. Vegetated or rock-lined channel		
	3. Drainage system stabilization	a. Vegetated Rock-lined channel	Maybe	High
		b. Piping		
	4. Disturbed area or slope stabilization	a. Retaining wall	Maybe	High
		b. Soil restoration		
		c. Revegetation		

Source Category/ Treatment Option	Potential Control Option	BMP	Quantifiable Load Reduction	Viability
		d. Soft coverage to pavement		
		e. Rock slope protection		
		f. Parking protection or enforcement		
	5. Distributed collection of pollutants	a. Sediment traps or drop inlets with sumps	Maybe	High
	6. Land use change	a. Redevelopment	Maybe	Low
		b. Conservation		
	7. Gully stabilization	a. Armoring	Maybe	High
	8. Private BMP implementation to reduce mobilization of pollutants	a. Slope stabilization	Yes	High
		b. Driveway paving		
		c. Vegetation and mulch		
		d. Parking protection		
		e. Gravel armor		
	9. Reduce Road Abrasives	a. Alternative deicing strategies	Yes	High
		b. Increased recovery from sweeping		
	10. Reduce Fertilizer Applications (recreational and residential)	a. Alternative fertilizer applications, conversion of turf to synthetics, etc.	Yes	High
		b. Change in fertilizer brand availability, educational efforts, management efforts	Yes	High
	11. Sewer Exfiltration and Septic System Management	a. Increased sewer system monitoring and maintenance	Maybe	High
		b. Point source removal and treatment	Maybe	Medium
	12. Animal Waste Management	a. Bird waste management, bird management, etc.	Yes	Medium
		b. Pet waste management, owner education	Yes	High
Stormwater Treatment	1. Volume and sed based treatment via pervious BMP	a. Detention basin	Yes	Medium
		b. Wetland basin		
		c. Retention basin		
		d. Infiltration basin		
	2. Volume and sed based treatment via impervious BMP	a. Pre-fabricated vault	Yes	Medium
		b. Hydrodynamic device		
	3. Flow based treatment via fabricated structural BMP	a. Media filter	Yes	Medium
		b. Regional treatment plant		
		c. Electrocoagulation		
	4. Flow based treatment via vegetated filtration BMP	a. Grass swale - biofilter	Yes	Medium
	5. Advanced treatment prior	a. Chemical dosing	Yes	Medium

Source Category/ Treatment Option	Potential Control Option	BMP	Quantifiable Load Reduction	Viability
	to infiltration to groundwater (applies as add-on to PCO 1-3)	b. Adsorptive media	Yes	High
		c. Vegetation management and maintenance	Maybe	High
		d. Vertical treatment strategies in dry wells	Yes	High
Groundwater Treatment	1. In-situ groundwater	a. Pump and treat	Yes	Medium
		b. Reactive walls	Maybe	Medium

4.3. Setting-Level Evaluation Approach

Considering the difficulties involved in estimating performance for individual PCOs and the unlimited number of potential combinations, the approach for this project will be to identify groups of PCOs that apply to particular Lake Tahoe Basin settings. These groups of PCOs will be identified as a "treatment option" for a particular setting and will typically combine PCOs that serve the primary load reduction functions (hydrologic source control, pollutant generation source control, and stormwater treatment). The treatment options will represent two levels of potential PCO implementation for particular Lake Tahoe Basin settings:

- **Current Practice** to represent the upper end of the present state of practice in the Lake Tahoe Basin, including a 25 percent implementation level for private property BMPs required by current code
- **Maximum Theoretical Load Reduction (MTLR)** to represent the maximum practical load reduction associated with advanced technology and intensive PCO application, assuming no pumping or export of flows from the catchment. The MTLR option will assume 100 percent implementation of private property BMPs required by current code.

Two treatment options will be identified for each of five settings. The settings will be defined at the scale of typical urban catchments (5-50 acres) and may include one or more land uses as an adaptation of the transect concept described in Section 2. This scale is appropriate for combining hydrologic and pollutant generation source controls with more centralized treatment PCOs.

In addition to the two treatment options in five settings, the SCG will evaluate the potential application of pump and treat PCOs in two of the most highly developed settings. This evaluation will assume that transfers or export of stormwater to regional treatment facilities is feasible and will estimate effectiveness of this treatment option by estimating achievable effluent concentrations in advanced active treatment facilities.

Groundwater load increases and reductions will be evaluated as an integral component of the treatment options by setting. In a particular setting, the effects of the group of PCOs that define a treatment option will be estimated on treated surface water outflows, treated groundwater inflows, untreated surface water outflows (bypasses), and untreated groundwater inflows (lacking advanced treatment). Surface water and groundwater loads will be tracked separately.

An exception to the integrated evaluation of surface water and groundwater will be evaluation of groundwater treatment options for in-situ pumping and reactive walls. These two PCOs apply only to groundwater rather than to the infiltrated component of surface water and will therefore be evaluated separately and independent of the settings.

Load Reduction Evaluation Methods

A brief description of the methods to be used in the above approach is as follows:

Step 1: Coordination with LSPC

The Watershed Model will be used to extrapolate the setting-scale evaluation conducted by the Urban Upland and Groundwater SCG to the basin-scale. Consequently the approach taken by the SCG needs to be aligned with the modeling approaches and architecture in the Watershed Model to ensure that the results of the SCG work are directly useful as inputs to the Watershed Model for the Lake Tahoe Basin-scale extrapolation. The SCG will review the modeling approaches and required inputs for the LSPC model with the watershed modeling team and refine the target outputs from the SCG evaluation accordingly.

Step 2: Define PCO Mass Balance Block Diagrams

PCOs will be defined in terms of simple mass balance diagrams that identify various components of inflowing and outflowing loads. An example for a detention basin with advanced adsorption for groundwater infiltration is shown in Figure 4-1. The diagrams will be used to ensure that PCOs are clearly defined conceptually in terms of unit processes and that stormwater and groundwater loads are accounted for separately but simultaneously in the performance evaluations.

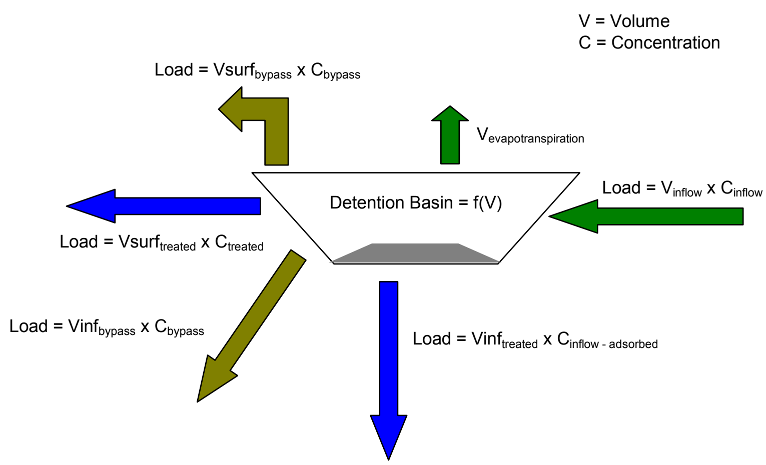

Figure 4-1. Conceptual model of detention basin PCO.

Step 3: Estimate Hydrologic Source Control PCO Effectiveness

For each PCO in the Hydrologic Source Controls, the SCG will estimate the effectiveness of the PCO in reducing pollutant loads (for each pollutant of concern) by land use classification. These estimates will be based on Lake Tahoe specific data to the extent feasible, but may also rely on empirical methods and data from other geographic areas and evaluation of probable effectiveness based on unit processes and fraction of runoff volume treated.

The estimates will necessarily be associated with simple hydrologic or hydraulic parameters, frequency or intensity of application, or other metrics. This step is necessary to define probable performance in terms of practical ranges in size or extent of PCOs, but will not define specific BMPs or recommend specific BMP design criteria. To the extent feasible, these parameters will be defined in terms of current or recommended practice from the literature, and if possible will be defined on a unit basis (e.g., impervious area inches of infiltration capacity). In some cases (e.g., impervious surface removal), simple assumptions such as percent of area treated may be required for quantification purposes. All such assumptions will be documented, along with the basis for performance estimates.

For Hydrologic Source Controls that result in increased loads to groundwater (e.g., infiltration galleries), the effects will be estimated in terms of increased loads for pollutants of concern. The effects on groundwater loads and stormwater flow reductions will be tracked separately, but will be associated with a single PCO by mass balance.

The result of this evaluation will be a table of PCO effectiveness by land use, similar to the example shown below.

Example PCO	Treatment Component	Example Landuses			Units
	Hydrologic	Single Family Residential	Highway	Commercial	
Decrease amount of runoff reaching catchment outlet	Flow	n/a	20-40%	0-10%	in/acre/unit of time
Private BMP implementation to detain and infiltrate runoff	Flow	60-75%	n/a	40-60%	in/acre/unit of time

Step 4: <u>Estimate Pollutant Generation Source Control Effectiveness</u>

For each PCO in the Pollutant Generation Source Controls, the SCG will estimate the effectiveness of the PCO in reducing pollutant loads (for each pollutant of concern) by land use classification. This evaluation will be parallel to that described above for the Hydrologic Source Controls, and results will be presented in a table similar to the example shown below.

	Pollutant	Single Family Residential	Highway	Commercial	
Reduce Road Abrasives	TSS	n/a	30-50%	20-40%	EMC
	TP	n/a	20-40%	15-35%	EMC
	SRP	n/a	0-10%	0-10%	EMC

Step 5: <u>Determine Achievable Effluent Concentrations for Lake Tahoe Basin Stormwater Treatment PCOs</u>

For each treatment PCO, estimates of treatment performance will be made on the basis of achievable effluent concentration basis. These estimates will not be associated with performance in a particular land use, because most treatment PCOs are applied to a catchment with mixed land use. Therefore, quantification in terms of percent reduction is probably not meaningful. Certain exceptions may be identified (e.g., treatment options for highway land use) during the evaluation. As for Steps 3 and 4, simple sizing parameters (e.g., impervious area inches of detention basin volume) will be required to define approximate sizes or extents of PCOs so that performance can be estimated.

Step 6: Define Settings and Treatment Options

a) Define Settings
Settings will be defined with assistance from SCIC to represent conditions in the Lake Tahoe Basin that can be used in the Basin-scale extrapolation. The settings will represent typical land use characteristics (e.g., density of development, characteristic impervious area, characteristic mix and configuration of land uses), and may also represent key physiographic characteristics (e.g., land surface slope) . The land use and physical characteristics that define a setting will be adapted from the transect concept illustrated in Figure 2-2.

b) Develop PCO Combinations to Define “Current Practice” and “MTLR” Treatment Options
For each setting, a combination of PCOs will be selected to represent each of the two Treatment Option levels. PCOs will be selected based on feasibility in the setting, estimated need for pollutant control, and probable cost effectiveness in terms of load reduction. The description of PCO combinations will use and build on the sizing parameters defined in Steps 3, 4, and 5 to define the Treatment Options. As Treatment Options are defined, limited analysis will be conducted to estimate, as nearly as possible, sizes or extents of facilities that appear to represent the most cost effective options.

Step 7: Estimate Overall Load Reduction for Each Setting and Treatment Option

a) Settings
The overall load reduction for each treatment option in each setting will be estimated using analytical methods, empirical estimates, components of the PLRE-STS developed during Phase 1 of the TMDL, or application of LSPC. The exact methodology may vary by setting, but will generally be guided by the framework established by PLRE-STS. The results of this evaluation will be presented as shown in Table 2-1, except results for treatment PCOs will not be presented by land use. Instead, an overall reduction by setting (transect) will be shown, assuming that centralized treatment PCOs operate on the combined land uses of the setting.

As for the evaluation of individual PCOs, this evaluation will track loads or load reductions to stormwater and groundwater simultaneously but separately in the form of a mass balance for each Treatment Option. It will also be formatted to show the fraction of the runoff volume treated and bypassed in the centralized treatment facilities or treatment trains and the fraction treated by advanced methods prior to infiltration, if applicable.

b) Pump and Treat Options
For two of the most developed settings, the load reductions associated with pump and treat options will be estimated. The conceptual model for this option will involve transfer of flows out of drainage catchments to regional treatment facilities. Load reductions will be estimated using estimates for effluent concentrations from advanced treatment and volumes of runoff treated.

c) In-Situ Groundwater Treatment
The treatment options described above will be evaluated as urban upland stormwater options, and their effects on groundwater loads will be quantified as an integral part of this evaluation. Groundwater treatment options for in-situ pumping and reactive walls apply only to groundwater, as opposed to the fraction of stormwater that infiltrates to groundwater, and will therefore be evaluated separately. For these PCOs, definition of a setting is probably not

necessary, and load reductions will be defined on a unit size basis (PCO size/volume or mass treated) that can be applied regionally.

Step 8: Estimate Annualized Costs for Each Treatment Option within a Setting
Estimates of annualized costs will be developed in a manner similar to that outlined in Section 2.3. Refinement of the cost estimating approach will occur as treatment options are developed.

Step 9. Provide Assistance to Basin-Wide Load Reduction Extrapolation
This step involves technical assistance and review to the watershed modeling team during extrapolation of site-scale evaluations to the Basin-wide scale.

Example LRM

The terms and values to be assembled in the LRM represent information which can be readily incorporated within the existing LSPC Watershed Model framework. Figure 4-2 illustrates how BMPs and treatment pathways can be represented in LSPC and identifies the relevant system components associated with Forest, Urban, and Groundwater SCG analysis efforts.

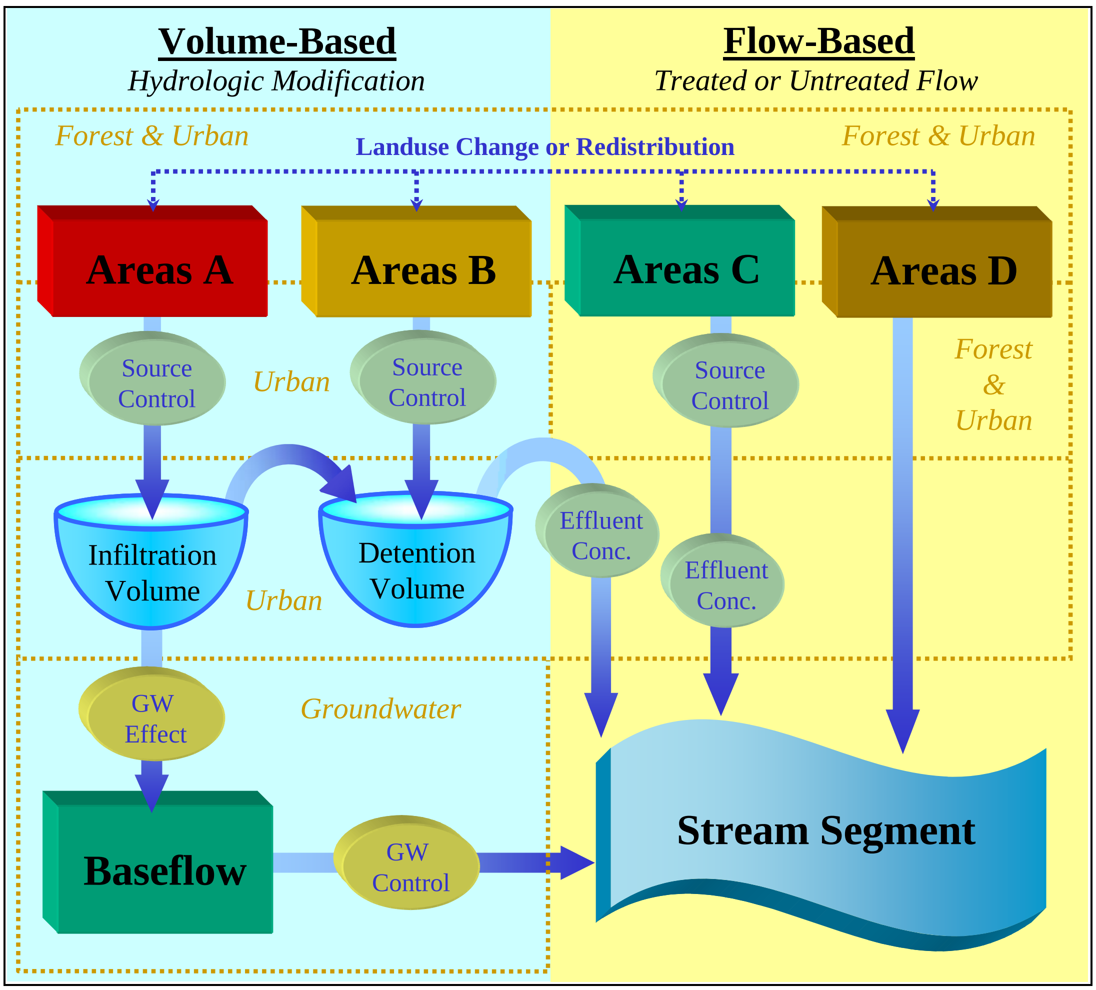

Figure 4-2. BMPs and treatment pathways as represented in LSPC, with SCG-related components identified.

Figure 4-3 shows an example LRM that contains BMPs and treatment pathway data fields for the Forest, Urban, and Groundwater SCGs. Table 4-2 lists the data components and corresponding definition units required to extrapolate to a setting-defined subwatershed level, and ultimately, to a Basin-wide level. The units of the required inputs are such that they can be readily scaled from 0–100 percent to analyze different levels of adoption.

A-Design Specifications for Hydrologic Modifation Controls

Transect/ Setting	Treatment Option	All Costs	Effectiveness Certainty (H,M,L)	Dominant Treatment Function	Treatment Component				
					Infiltration Volume (in/acre)	Design Flow or Detention Volume (in/acre or cfs)	Sediment (Effluent Conc)	TN (Effluent Conc)	TP (Effluent Conc)
1	1	$	(H,M,L)	Volume Based	1.5	1	3	0.1	0.01
				Flow Based	n/a	20	5	0.2	0.02
	2	$	(H,M,L)	Volume Based	X	X	X	X	X
				Flow Based	n/a	X	X	X	X
	n	$	(H,M,L)	Volume Based	X	X	X	X	X
				Flow Based	n/a	X	X	X	X
2	...	...	...	...	...	...	...	...	...
				...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...
				...	...	...	...	...	...
N	1	$	(H,M,L)	Volume Based	Z	Z	Z	Z	Z
				Flow Based	n/a	Z	Z	Z	Z
	n	$	(H,M,L)	Volume Based	Z	Z	Z	Z	Z
				Flow Based	n/a	Z	Z	Z	Z

B-Corresponding Areas of Influence and Source Controls

Transect/ Setting	Treatment Option	Landuse	Area of Influence (acres)	Treatment Component		
				Source Control		
				Sediment (%-Red)	TN (%-Red)	TP (%-Red)
1	1	Roads	1.5	10%	15%	20%
		Residential	30	0%	0%	0%
		Commercial	25	10%	15%	20%
		etc.	X	X	X	X
	2	Roads	Y	Y	Y	Y
		Residential	Y	Y	Y	Y
		Commercial	Y	Y	Y	Y
		etc.	Y	Y	Y	Y
	n	Roads	Z	Z	Z	Z
		Residential	Z	Z	Z	Z
		Commercial	Z	Z	Z	Z
		etc.	Z	Z	Z	Z
2	...	...	...	...	...	...
	...	...	...	...	...	...
N	Z	Z	Z	Z	Z	Z
	Z	Z	Z	Z	Z	Z

Figure 4-3. Example LRM for the Urban Upland, Forest Upland and Groundwater SCGs using the Watershed Model as an extrapolation tool.

This LRM displays all settings for the source category and all of the treatment options evaluated for each setting. All applicable cost and the effectiveness certainty will be captured for each setting. The settings will be sub-divided into three treatment functions which include:

- Source control
- Volume-based treatment (which may include an infiltration component)

- Flow-based treatment

The dominant features or functions are further divided into treatment components that are based on the pollutant definitions and flow. For each treatment option and component, the SCG will be asked to determine design volumes/flows and effluent concentrations for hydromodification controls or percent reductions for direct source controls. Since each treatment option also has an area of influence, a table of influenced areas is a secondary requirement. For structural controls, this means the contributing drainage area; whereas for direct source controls, it represents area that undergoes source control. There may be some treatment options which contain a combination of hydromodification and source control. Likewise, there may be treatment options which are purely source control; therefore, they will not appear in the hydromodification table. These two tables together represent the LRM for defining treatment activities for each setting.

4.4. Basin-Wide Load Reduction Extrapolation

The results of the site-scale evaluations will be used in the LSPC Watershed Model for the Basin-wide extrapolation. In general, the Watershed Model will be used to represent treatment options that combine source control, infiltration, detention, and treatment plant options on a subwatershed basis. Since these types of controls affect combinations of land uses within a given drainage area, they can be aggregated on a subwatershed basis to preserve drainage direction.

Urban controls will take the form of at least one or a combination of the following: (1) land use change or redistribution, (2) direct source controls represented as reduced EMCs by land use, (3) flow and/or volume based structural controls that involve design flows and design volumes for infiltration and/or detention volumes and their associated drainage areas, and (4) effluent concentrations for flow and volume based controls.

The Basin-wide evaluation begins with spatial analysis to define the settings where particular PCOs are applicable. Feasibility information from the site-scale evaluations will be used to estimate the area in which a PCO may be associated with a setting, but unlikely to be feasible due to variations in conditions. As noted above, it is expected that the typical treatment option will be generally feasible for most areas in a particular setting, but the MTLR may be feasible in smaller portions of the total area associated with a setting.

4.5. SCG and Review Group Membership and Expertise

Northwest Hydraulic Consultants (**nhc**) will lead the Urban Upland component of the SCG. Ed Wallace, a principal with nhc, is designated as the Urban Upland SCG lead. Mr. Wallace has 25 years of engineering experience in water resources planning, analysis, design, and construction. Mr. Wallace's Lake Tahoe Basin experience includes planning and design of water quality improvement projects, hydrologic and hydraulic analysis, construction management, and completion of over 40 assignments for the California Tahoe Conservancy (CTC). The qualifications of the Urban Upland SCG Contributors and Research Assistant are summarized in Table 4-2. The overall group qualifications include:

- Over 100 years of combined experience in stormwater management, modeling, and monitoring
- Lake Tahoe Basin project implementation expertise
- Nationally recognized experts for BMP design, monitoring & evaluation

Table 4-2. Urban Upland SCG Members and Expertise

Person	Role	Affiliation	Expertise
Ed Wallace	Lead	nhc	Principal for **nhc** with 25 years of engineering experience in water resources planning, analysis, design, and construction. Lake Tahoe Basin experience includes planning and design of water quality improvement projects, hydrologic and hydraulic analysis, construction management, and completion of over 40 assignments for the CTC.
Brent Wolfe	Research Assistant	nhc	Engineer for **nhc** with 6 years of experience in water resources planning, modeling, and analysis. Lake Tahoe Basin experience related to stormwater projects includes water quality modeling, monitoring, planning, and design.
Eric Strecker	Contributor	GeoSyntec	Principal for GeoSyntec Consultants with 20 years of experience in stormwater management, especially in the design, monitoring, and evaluation of BMPs. Lake Tahoe Basin experience includes a feasibility and effectiveness study of project level and basin.
Dr. Rob Odell	Contributor	nhc	Senior engineer for **nhc** with 9 years of experience in water resources engineering with specialized expertise in hydraulic and sedimentation modeling.
Marc Leisenring	Contributor	GeoSyntec	Engineer for GeoSyntec Consultants with 5 years of experience in stormwater management, BMP performance analysis, and modeling. Lake Tahoe Basin experience includes technical model development of the pollutant load reduction methodology created in Phase 1 of the TMDL.
Dr. Peter Mangarella	Contributor	GeoSyntec	Principal for GeoSyntec Consultants with 30 years of experience in stormwater management and urban runoff water quality modeling. Lake Tahoe Basin experience includes project management of the pollutant load reduction methodology created in Phase 1 of the TMDL.
Dr. Nicole Beck	Contributor	2ND NATURE	Principal of 2NDNATURE, implemented pollutant fate and transport studies at a number of Lake Tahoe detention/infiltration BMPs over the past 5 years. Academic training in groundwater modeling/solute transport.

2NDNATURE will lead the Groundwater component of the SCG. Dr. Nicole Beck, a principal with 2NDNATURE, is designated as the Groundwater SCG lead. Dr. Beck has implemented pollutant fate and transport studies at a number of Lake Tahoe detention/infiltration BMPs. Dr. Beck's academic training is in groundwater modeling/solute transport. The qualifications of the Groundwater SCG Contributors and Research Assistant are summarized in Table 4-3. The overall group qualifications include:

- Over 40 years of combined experience in groundwater protection and analysis
- Contributions to several recent groundwater investigations in the Lake Tahoe Basin
- Related investigations and expertise enables investigation of stormwater infiltration on groundwater

Table 4-3. Groundwater SCG Members and Expertise

Person	Role	Affiliation	Expertise
Dr. Nicole Beck	Lead	2ND NATURE	Principal of 2NDNATURE, implemented pollutant fate and transport studies at a number of Lake Tahoe detention/infiltration BMPs over the past 5 yrs. Academic training in groundwater modeling/solute transport.
Maggie Mathias	Research Assistant	2ND NATURE	Science associate with 2NDNATURE. Performed all technical aspects of pollutant fate and transport monitoring, modeling and communications.
Pat Hoban	Contributor	2ND NATURE	P.G. with more than 15 years of experience managing groundwater remediation, characterization, and water supply projects for a wide range of public and private clients. Teams with 2NDNATURE on Lake Tahoe groundwater studies.
Carl Thodal	Contributor	U.S. Geological Survey (USGS)	USGS Hydrogeologist and has conducted number of groundwater studies in Lake Tahoe Basin.

The Urban Upland and Groundwater Review Group represents significant local and regional expertise to help guide investigations and provide feedback of work products. The Review Group members will be asked to provide Lake Tahoe and agency-specific input related to this Work Plan and the results of PCOs analyzed. The Review Group members will also provide an important communication function, informing their organizations of SCG plans and initial SCG findings. The suggested Review Group members are summarized in Table 4-4. Suggested members are still being contacted to determine their availability and willingness to participate. Up to six Special Consults will be identified within the Review Group based on individual experience, perspective, and availability to participate. Special Consults will provide detailed review and comment on selected approaches and developed work products, while representing the perspective of members of the larger Review Group.

Table 4-4. Proposed Urban Upland and Groundwater Review Group Members and Key Information

Person	Perspective	Affiliation
Kansas McGahan	Project Implementation	Placer County, Storm Water Quality Improvement Committee (SWQIC)
Steve Kooyman	Project Implementation	El Dorado County, SWQIC
Larry Benoit	Water Quality Policy	TRPA, Water Quality TWG
Karen Fink	Transportation Planning	TRPA, Transportation TWG
Gordon Shaw	Transportation Planning	Transportation TWG and Forum
Catherine Schoen	Project Implementation	USFS, Lake Tahoe Interagency Monitoring Program (LTIMP)
Theresa Jones	Project Implementation	Nevada Department of Transportation
Rich Williams	Project Implementation	Caltrans
Jennifer Quickel	Project Implementation	CSLT, SWQIC
Leo Popoff	Science/Community	Author of Basin Watch Column
Cliff Lawson	NDEP (Stormwater)	NDEP (Stormwater)
Liz Harrison	Nevada Funding	NDSL, Water Quality TWG/SWQIC
Kimble Corbridge	Project Implementation	Washoe County, SWQIC
Ron Roman	Project Implementation	Douglas County, SWQIC
Bob Larsen	TMDL	TMDL/SWQIC General Liaison
Robin Mahone	TMDL	TMDL/SWQIC H&H Liaison
Russ Wigart	Monitoring & Project Implementation	CTC
Ivo Bergson	Drinking Water	South Tahoe Public Utility District (STPUD), Water Quality TWG
Graham Fogg	Groundwater Research & Science	USGS
Russ Land	Groundwater Protection	Groundwater Protection

5. Forest Uplands SCG Specifics

Forested land-use accounts for the vast majority of land area in the Lake Tahoe Basin. The Watershed Modeling efforts of the TMDL's first Phase indicated the importance of this land-use by demonstrating that significant portions of the Lake Tahoe Basin-wide pollutant loads come from this source.

The Forest Upland SCG will use a combination of primary field research information, laboratory analysis, and literature values to estimate the setting-level effects of PCOs. The Forest SCG will identify PCOs and their characteristics and estimate the hydrologic and loading changes resulting from implementing PCOs. The setting-level effectiveness will be extrapolated Basin-wide using the Watershed Model.

5.1. Source Discussion

The forested uplands portion of the Lake Tahoe Basin encompasses a wide range of land uses and management activities. We have grouped these distinct land uses into settings that have similar management goals, intensities and types of disturbance, and load reduction opportunities. Each of the four major forested uplands settings are characterized below.

Forestry and Watershed Management Areas – These areas are managed primarily for forest and watershed health, wildlife habitat, clean water, and other natural resource and beneficial use goals. The USFS manages most of these areas in the Lake Tahoe Basin. However, a number of other land managers also manage these lands including Nevada Division of Forestry, CTC, private land owners (California Department of Forestry oversight) and individual fire protection districts. The Forest and Watershed Management sub-category involves thinning and other fire management activities as well as post-fire activities. The SCG will assess a range of impacts from these activities including disturbances associated with both proactive and reactive forest management activities.

Roads, Trails, and Other Impervious and Semi-Impervious Surfaces – This category includes all dirt areas that have been disturbed and compacted. Also in this group are paved areas. Many forested areas include highways and paved USFS, county and CTC system roads, such as the Mt. Watson road network, the McKinney Creek road and others. Management issues include water flow and treatment management and related roadside issues. Integrated Environmental Restoration Services (IERS) has been heavily involved in BMP design and implementation for roads and other impervious surfaces.

Ski Slopes – Ski slopes represent a great opportunity for reducing sediment loading to Lake Tahoe. There is a wide range of disturbance types and intensities associated with creating new ski runs and managing existing ski runs, ranging from drastically disturbed to moderate levels of soil compaction. Most ski slopes are also subject to ongoing operational impacts such as grooming, vehicle travel, subsurface infrastructure improvements, mountain-biking and hiking. New ski run clearing techniques offer great promise for accomplishing ski area goals while minimizing soil disturbance and erosion potential.

Road Cut and Fill Slopes – Cut and fill slopes are a unique land use category since they usually involve cutting into subsoil and/or parent material and completely reworking soil. They are also prone to continual disturbance and impacts such as foot traffic, sand application from snow removal activities, and wind erosion. Cut and fill slopes will be considered separately from the roads themselves since the PCOs used to reduce erosion are quite different. The definition of this setting will be discussed with modelers to determine how the Watershed Model will treat road cuts verses roads.

A great deal of the forest management activities in the Lake Tahoe Basin are either aimed at or at least have a component of fire hazard reduction in those activities. The potential for catastrophic wildfire in overstocked timber stands is very real. Many of the treatment activities, which are included as PCOs in the SCG's list, have benefits and costs associated with them. The benefits include reducing high intensity wildfires. However, it is difficult if not impossible to assign any reliable value to those efforts based on the probability of wildfire reduction. Therefore, that issue will not be directly addressed. It will be assumed that these efforts will result in reduced probability of wildfire. It will, however, be assumed that each of these activities and PCOs will be associated with their own potential for increased sediment and nutrient movement through the watershed. For instance, broadcast and pile burns may allow for an increase in runoff and nutrient potential. Values will be assigned for sediment and nutrient potential within these efforts, thus identifying a cost/benefit/effectiveness for each of these PCOs.

5.2. Initial Evaluation of PCOs

The Forested Uplands SCG has done a preliminary assessment of PCOs for the source category. Table 5-1 lists potential PCOs grouped by setting, providing a qualitative ranking of viability, potential measurement methods for each PCO, and whether or not PCO effectiveness has been measured in the Lake Tahoe Basin.

Load Reduction Quantification

All proposed PCOs in Table 5-1 are considered to be quantifiable using some or all of the proposed measurement methodologies included in Table 5-2. The Forested Uplands SCG already has much of the data and information needed to quantify potential load reductions for these PCOs. However, where data gaps exist, additional research data will be gathered to help quantify load reductions for selected PCOs. Load reductions will be presented as minimum and maximum values for each sub-category of PCOs to provide the SCIC with a realistic sense of the range of potential effectiveness.

Viability

PCOs have been assigned a qualitative ranking of viability (high, medium or low). At this point, viability rankings are subjective and based on the professional experience of the SCG members. The following factors are being considered as criteria for ranking PCO viability:

- Technical feasibility – are the materials and technology readily available to develop and implement a particular type of PCO?
- Ease of implementation – how much time/effort will it take to implement the PCO?
- Functionality/effectiveness over time – what are the expected load reductions over time for each PCO?
- Cost and maintenance requirements – what are the capital and O&M costs associated with the PCO? What are the anticipated lifetime costs of the PCO?

Table 5-1. Initial PCO Assessment for Forested Uplands Settings

Setting	PCO	Measured Locally	Measurement Methodologies	Viability
Forestry and Watershed Management	Limit # of trips	No	3,7	High
	Broadcast burn	?	1,2,3,4,5	Med-High
	Chip and remove	No	1,2,3,4,5	High
	Chip and scatter	No	1,3,4,5	Med-High
	Mastication	Yes	1,3,4,5	Med-High
	Over-the snow work	No	1,3,4,5,6	High
	Pile and burn	?	1,2,3,4,5	High
	Forwarding	No	1,3,4,5	Med-High
	Grapple (tong-toss) skidding	No	1,3,4,5	High
	Skidding	?	1,3,4,5	High
	Skyline	No	1,3,4,5	Med-High
	Helicopter logging	No	1,3,4,5	Med-High
	Yarding	No	1,3,4,5	Med-High
	Fire suppression activities	No	1,3,4,5,6	High
	Post-fire treatment activities	Yes	1,3,4,5,6	High
	Mulching (& type)	Yes	1,2,4,5	Med-High
	Ripping-sub-soiling (& depth)	Yes	1,3	High
	Road removal	Yes	1,3,4,5,6	Med-High
	Road surface restoration	Yes	1,3,4,5,6	High
Roads, Trails and Other Impervious Surfaces	Insloping	No	8	High
	Outsloping	No	5,8	High
	Paving	?	2,8	Med-High
	Rock surface	No	2,8	High
	Water bars	No	2,8	High
	Watering	?	2,8	Med-High
	Curb and gutter	?	2,8	Med-High
	Filter berms-pine needle	Yes	2,8	High
	Flow path check dams	No	2,8,9	High
	Infiltration ditch	Yes	2,3,8,9	High
	Infiltration gallery	Yes	9	Med-High
	Infiltration swale	Yes	1,2,3,4,5,6	Med-High
	Other (see Urban Uplands)		Various	
	Rock line ditch	No	2,8	Med-High
	Settling pond	No	2,8	Med-High
	Treatment swale	Yes	1,2,3,4,5,6	Med-High
	Vegetated swale	Yes	1,2,3,4,5	Med-High
	Vegetated filter strips (VFS)	No	2,8	Med-High

Setting	PCO	Measured Locally	Measurement Methodologies	Viability
	Traffic exclusion	Yes	1,2,3,4,5	Med-High
Ski Slopes	Full treatment (suite x)	Yes	1,2,3,4,5,6	High
	Hydroseeding	Yes	1,2,3,4,5,6	Low-High
	Irrigation	Yes	1,3,4,5	Med-High
	Mulch (& type)	Yes	1,2,4,5	Med-High
	Mycorhizzae	?	10,11	Med
	Organic matter amendment	Yes	1,2,3,4,5,6	Med-High
	Other amendments	No	Various	
	Planting (& type)	Yes	12,13	Low-Med
	Ripping (& depth)	Yes	1,3	High
	Seeding (& type)	Yes	1,3,4,5	High
	Soil roughness	Yes	1,2,3,4	High
	Tilling (& depth)	Yes	1,2,3,4,5	High
	Track walking	Yes	1,2,3,4,5	Low-High
	Clearing and plucking	Yes	1,3,4,5	Med-High
	Mastication	Yes	1,3,4,5	Med-High
	Smooth grading	Yes	1,2,3,4,5	Low-High
Road Cut and Fill Slopes	Drilling (& depth)	Yes	1,3,4,5	Med-high
	Engineering	No	2,5,8	Low-High
	Hydroseeding	Yes	1,2,3,4,5,6	Low-High
	Irrigation	Yes	1,3,4,5	Med-High
	Mulch	Yes	1,2,4,5	Med-high
	Mycorhizzae	?	10,11	Med
	Organic matter amendment	Yes	1,2,3,4,5,6	Med-High
	Other amendments	No	Various	
	Planting (& type)	Yes	12,13	Low-Med
	Retaining structures	No	2,3,5	Low-High
	Ripping (& depth)	Yes	1,3	High
	Seeding (& type)	Yes	1,3,4,5,6	High
	Soil roughness	Yes	1,2,3,4	High
	Tilling (& depth)	Yes	1,2,3,4,5	High
	Track walking	Yes	1,2,3,4,5	Med
	Traffic exclusion	No	1,2,3,4,5	Med-High

Table 5-2. PCO Measurement Methodology Key

Code	Method	Description
1	Rainfall Simulator	Simulated rainfall event where infiltration, runoff and erosion sediment yield rates are determined and runoff is collected for nutrient and particle-size analyses.
2	Runoff Simulator	Simulated overland flow event where infiltration, runoff and erosion (sediment yield) rates are determined and runoff is collected for nutrient and particle-size analyses.
3	Cone Penetrometer	Probe that measures resistance to force in pounds per square inch as it is inserted into the soil. Penetrometer depth is a useful index for infiltration rates.
4	Cover Point Monitoring	Vegetation, mulch and other soil cover is measured at points along transects using a laser pointer. Methods used ensure a statistical confidence level of at least 80%.
5	Shear Strength Assessment	A hand-held shear vane is used to measure the shear strength of soil in kilopascals (kPa).
6	Soil Nutrient Analysis	Soil samples are collected in the field then sent to a soil lab for nutrient analysis. Key test parameters include total Kjeldahl nitrogen, organic matter, nitrate, phosphorous and pH.
7	Implementation Monitoring	Assessment during or immediately following project completion to determine if treatment goals were met.
8	Water Quality Testing	Testing for turbidity and/or nutrients in runoff downstream or downslope of treatment area.
9	Flow Rate and Draw-down Assessment	Auto-samplers and flumes with flow gauges are installed upstream and downstream of key hydrologic infrastructure (infiltration ditches, galleries, basins, etc) to measure inflow and outflow during storm events. Infiltration/draw-down rates are calculated from this data.
10	Microbial/Mycorrhizal Spore Counts	Lab procedures that count mycorrhizal spore populations by species.
11	Root Colonization Assessment	Lab procedures that count the type and amount of root colonization by mycorrhizal spores.
12	Plant Census	Plants are counted at least 3-4 months after planting and again in subsequent seasons to determine plant survival rates for different species.
13	Plant Vigor Assessment	Canopy diameter and leader length are measured annually to determine growth rates and overall plant vigor.

Note: measurement methodologies described above are predominantly field methods- all data to be used in the SCG's analysis has already been collected.

5.3. Setting-Level Evaluation Approach

A great deal of important data and information already exists on PCO performance in the Lake Tahoe Basin. Members of the Forest Uplands SCG have been using simulated rainfall and other monitoring techniques to quantify the performance (in functional terms, such as infiltration vs. runoff, nutrient cycling) of a wide variety of restoration techniques and BMPs for nearly a decade.

Similar to the Urban Uplands and Groundwater SCG, the Forest Uplands SCG will use the Watershed Model for Basin-wide extrapolation. As a result, the discussion in Section 4.3 regarding the formulation and contents of the LRM is also applicable here and should be reviewed as part of the Forest Uplands specific Work Plan.

Ultimately, forest upland controls will either take the form of land use change (redistribution of land use area from a category of higher disturbance to lower disturbance) or source control (EMC reductions for existing categories). Small-scale predicted reductions can be aggregated to a subwatershed level using GIS operations. Finally, the subwatershed-specific reductions can be applied to existing loads and/or particile size distributions to represent Basin-wide adoption as needed.

Load Reduction

Sediment detachment, transport, and delivery always begins at the local scale on the order of square meters or "site" scale. Sediment reduction is a function of soil type and land slope (e.g., exponential relationship between slope and sediment yield) at the site scale. We propose estimation of possible load reductions associated a range of treatment intensities (High, Medium, Low) for PCOs and treatment options applicable to each setting. These load reductions will be compared to disturbed bare soil conditions. With what quantified knowledge is available, a LRM will be developed with expected reductions in sediment yield, D_{10} particle-sizes and nutrients for PCOs in both granitic and volcanic soil types.

Cost

Minimum and maximum costs will be estimated for each selected PCO. Costs will include capital investment costs, average annual O&M costs, annualized costs, and cost per unit effort. IERS has already started developing cost estimates for different ski slope and forestry treatments through the collaborative research being conducted with the California Alpine Resorts Environmental Cooperative (CAREC). Costs for many of the other PCOs can be estimated based on IERS's contracting experience. The SCG will also look to cost information from other public projects inside and outside of the Lake Tahoe Basin and will project costs for new and emerging technologies.

Uncertainty

Uncertainty is a major component of assigning values for PCO effectiveness. Where models are the sole basis of an approximation, that uncertainty is likely to be orders of magnitude from the true value, especially where the models have not been calibrated with real data and/or calibration tests. The sediment delivery reductions associated with various PCOs is largely speculative as there is little quantified data available about even the simplest treatment options in the Lake Tahoe Basin. The SCG's experience and research in the field thus far has enabled them to develop a level of "professional judgment" as well as quantified output on how well some PCOs perform for a given level of treatment effort. That knowledge will be used with published literature values to provide estimates with an associated level of anticipated uncertainty in each load reduction estimate. The SCG will also discuss and qualify where the uncertainty lies (if possible) and what actions might be taken to reduce uncertainty, such as field validation and model calibration.

Legacy Impact Consideration

Within the Forested and Watershed Management Area setting a special attention will be directed to analyzing legacy impacts and recovery periods from activities such as grazing, abandoned roads, and old ski runs. It is not clear to what extent these legacy disturbances affect runoff and sedimentation. The SCG will consider these legacy disturbances in the evaluation of PCO use. The SCG can rely on actual field measurement of some of these impacts since members of the Forest Uplands SCG have been involved in monitoring a range of 'legacy impacts' over the past several years. It should be noted that, while vegetation has been used to suggest 'recovery,' members of the SCG have found that this is often not the case. The SCG will use its existing understanding of this actual potential for *functional* recovery to help estimate potential load reductions.

Roads and Trails

The USFS Lake Tahoe Basin Management Unit (LTBMU) has recently completed a water quality risk assessment for 120 miles of unpaved roads on USFS–managed land in the Lake Tahoe Basin. All road segments have been measured, characterized (slope angle, soil type, insloped/outsloped) and entered into a GIS database. The Water Erosion Prediction Project (WEPP) model has been used to determine flow characteristics and pollutant loading for all low- medium- and high-risk road segments. Following treatment, an assessment of BMP implementation effectiveness was also completed. The findings from the roads risk assessment are being compiled in a report that will be complete by January 2007. The Forest Uplands SCG will work closely with the USFS to ensure that the findings from their water quality risk analysis for roads are captured in the LRM.

The USFS is engaging in a similar analysis related to analyzing pollutant load reduction from treating trails. This analysis, however, is just beginning and will not be complete during the project period. As a result, the Watershed Modelers and USFS investigators will work together to determine how to best incorporate preliminary information into the overall SCG analysis and watershed modeling efforts.

Forest Health/Fuels Reduction

All USFS forest health/fuels reduction projects are being assigned an equivalent roaded acre (ERA) coefficient as a way of estimating the impact of their operations on water quality. Each project is also being assigned a recovery coefficient based on a 20-year recovery time. Field monitoring is being conducted before and after treatments to help validate these coefficients, which are based solely on professional judgment. Field monitoring includes direct measurement of key WEPP model parameters including infiltration capacity (K_{sat}), bulk density, and soil cover. K_{sat} results are then compared to ERA coefficients and the results are being used to help calibrate the effective hydraulic conductivity parameter in the WEPP model. This process has already been used to estimate the impacts of a wide variety of treatment methods, including hand-thinning, mechanized thinning (forwarding), and pile burning. A report is due in January 2007 that will report the findings of this effort. Data from this effort will be combined with other available data and used to help quantify hydrologic and pollutant loading impacts of forest health activities on water quality.

5.4. Basin-Wide Load Reduction Extrapolation

Similar to the Urban Upland and Groundwater SCGs, the Watershed Model will be used to perform the Basin-wide extrapolation of pollutant load reductions. In general, the Watershed Model will represent the hydrologic and loading changes by either changing land use erosion potential classifications or modifying the loading from a land use as a source control. If revegetation is involved, this will most likely be represented as a land use change from a category of high runoff to a low runoff. Source control will be represented as direct reductions to existing loads. It is possible for a land use change to perform both functions in some instances, since lower runoff will result in lower load without any additional source control. Further details on this approach are described below.

The LSPC model contains information from GIS layers such as soil type, slope, and land use. The "Vegetated Unimpacted" land use category was further refined during model calibration into five erosion potential (EP) classifications as determined from Simon (2003). Using a set of original pixilated GIS layers (soil, slope and vegetative cover) the Forest Upland SCG will develop a class of applicable PCOs and associated reduction estimates for runoff rates, sediment, and fine particle loading for the various pixel combinations. These pixilated reductions can be aggregated by the existing five EPs to determine spatially variable reductions by land use-subwatershed combination. If the pixilation does not conceptually match the existing five EP groups, these groups can be refined as needed (up to 10 EP groups, for example).

The estimated sustainability, duration of effectiveness, relative feasibility/viability, and level of uncertainty associated with each possible implementation will be identified for each PCO class. Possible reductions in runoff rates, or increased infiltration rates associated with the PCOs per pixel and their subsequent downstream effects, will also be considered and developed to provide information to the Stream Bank Erosion and the Urban Uplands and Groundwater SCGs. The pixel-based PCO information will essentially serve as an additional GIS-like layer feeding into the relational database and hydrologic process subroutine aspects of LSPC. The flowchart in Figure 5-1 illustrates the proposed process.

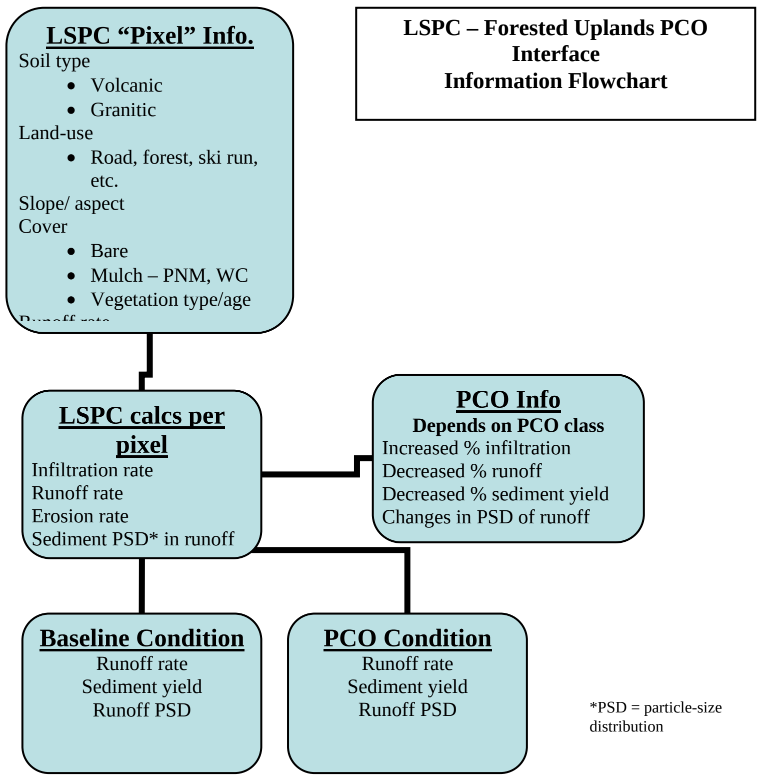

Figure 5-1. Flow chart showing how LSPC will be used to incorporate information regarding Forest Upland PCO effects on hydrology and pollutant transportation.

5.5. SCG and Review Group Membership and Expertise

The Forested Uplands SCG is lead by Michael Hogan, principle of Tahoe City-based Integrated Environmental Restoration Services (IERS). Michael has been involved in erosion control and restoration in the Lake Tahoe region for more than 20 years. His company, IERS, has been focused on efforts to improve erosion control and restoration techniques through scientific investigation, monitoring, and project implementation. He has worked with the USFS (LTBMU and others), Lahontan, TRPA and the various counties throughout the Lake Tahoe Basin. IERS has done extensive collaborative planning and on-the-ground erosion control research with ski resorts in the Lake Tahoe Basin and lead the formation of the CAREC. IERS is currently working to establish a similar adaptive management-based research and planning working group to focus on forest management issues. IERS is involved with a number of cutting edge projects including the Upper Cutthroat Urban Erosion Control Project, which is the first project of its kind to use real time measurement to assess the benefits of the project. IERS is working in collaboration with Placer County, USFS, CTC, Desert Research Institute and UC Davis on this project.

Table 5-3. Forested Uplands SCG Members and Expertise

Person	Role	Affiliation	Expertise
Michael Hogan	Lead	IERS	▪ Soil scientist, restoration and erosion control specialist ▪ 15 years erosion control and restoration experience ▪ Forest ecology sub-specialty ▪ Published Forest Management article 2006 ▪ P7 Soils/Stream Environment Zone (SEZ) TWG member
Kevin Drake	Research Assistant	IERS	▪ 2 years of erosion control/restoration project design, monitoring and implementation oversight ▪ 2 years of land use and environmental planning ▪ Degrees in Forestry and Urban and Regional Planning
Dr. Mark Grismer	Contributor	UC Davis	▪ Professor/researcher, UC Davis Hydrology and Civil Engineering ▪ Member soils graduate group ▪ 7 years upland and forest erosion and restoration research in the Lake Tahoe Basin
Wes Chrisitiansen	Contributor	USFS LTBMU	▪ WEPP modeling for USFS projects and investigations
Theresa Lupe	Contributor	USFS LTBMU	▪ WEPP modeling for USFS projects and investigations, expertise in monitoring effects of fire
Jim Harris	Contributor	USFS LTBMU	▪ WEPP modeling for USFS projects and investigations
Bob Coats	Contributor	UC Davis	▪ Decades of experience performing statistical analysis of natural systems and water quality issues in the Lake Tahoe Basin ▪ Member of UC Davis faculty with dozens of publications related to Lake Tahoe issues and natural resource issues

The Forested Uplands Review Group combines a great deal of experience from public agencies, special districts, universities, and private consultants. This group will provide technical input, guidance, and regular review of work products. The suggested Review Group members are summarized in Table 5-4. Suggested members are still being contacted to determine their availability and willingness to participate.

Table 5-4. Forested Uplands Review Group Members and Expertise

Person	Perspective	Affiliation
David Fournier	Forest Health, Fire & Fuels	USFS, Pathway Vegetation TWG
Woody Loftus	Soils & Soil Survey	Natural Resources Conservation Service (NRCS), Soils & SEZ TWG
Dr. Wally Miller	Forest and Fire Research	University of Nevada Reno
Joe Barron	Public Lands Management	NDSL, Soils TWG
Roland Shaw	Public Lands Management	NDSL, Vegetation TWG

Person	Perspective	Affiliation
Peter Maholland	Public Lands Management	NV Division of State Parks, Vegetation TWG
Bob Larsen	Restoration Project Review & Regulations, TMDL	Lake Tahoe TMDL Team, SCIC Liaison
Kim Gorman	TMDL	Lake Tahoe TMDL Team, Soils/SEZ TWG Liaison
John Pang	Urban & Wildland Fire	Chief Meeks Bay Fire Districts, Lake Tahoe Regional Fire Chiefs Association
Martin Goldberg	Urban & Wildland fire, SEZ Treatment	Lake Valley Fire District, Urban Interface Fuels Officer
Jerry Dion	Environmental Biology & Management, Veg Ecology	Tallac Applied Ecology; Former TRPA Veg and EIP program manager
Zach Hymanson	Science Program Manager, Forestry	Tahoe Science Consortium, CTC

5.6. Collaboration and Coordination with USFS LTBMU

The largest percentage (approximately 80 percent) of forested uplands is managed by the USFS LTBMU. The Forest Uplands SCG has already been coordinating and collaborating with the LTBMU on related projects and processes. These efforts include the Heavenly Master Plan Environmental Impact Statement facilitation and monitoring program guidance, development and facilitation of the Ski Guidelines/CAREC process, and review of forest management monitoring efforts. These efforts will continue and will become more focused as the TMDL process continues. Current and potential coordination and collaboration efforts are described below:

Past and current efforts

- On-call restoration contract with LTBMU
- Heavenly Master Plan Environmental Impact Statement facilitation and monitoring program development
- Development and facilitation of CAREC group and Ski Area Guidelines process
- Review of forest management monitoring efforts
- Official LTBMU/TMDL SCG interaction

Future efforts

- Formation of ad-hoc group to share, improve, and standardize forest management strategies and practices
- Monitoring, modeling, and research in an effort to apply real-time field research data to improve accuracy of commonly applied models such as WEPP.

A meeting was held between the USFS and the Forest Uplands SCG on November 29 to determine how the SCG will actively involve USFS staff in the SCG investigations. Several reports and data sets from recent USFS research are nearly complete and will help fill some of the data/information gaps that exist for calculating load reductions in forested uplands settings. Table 5-5 presents a preliminary schedule for the sharing of USFS reports and data sets with the Forest Uplands SCG. The Water Quality Risk Assessment Report for Roads and the Water Quality Risk Assessment Report for Forest Treatments have been developed to provide direct input into the TMDL modeling efforts. Each of these reports will be reviewed by the SCG and Watershed Modelers and meetings will be convened to clarify findings, to review data, discuss implications on load reduction planning, and determine how to fully incorporate findings into the setting-level and Basin-wide analyses.

Table 5-5. Reports to Be Incorporated Into Forest SCG Research

Report	Completion Date	Source
Water Quality Risk Assessment Report for Roads	January 2007	USFS
Water Quality Risk Assessment Report for Forest Treatments	January 2007	USFS
North Shore Travel Management Plan EA	Existing	USFS
USFS 5-year management plans, maps and GIS data	Winter/Spring 2007	USFS
Watershed Improvement Needs Inventory	Existing	USFS
Basin-Wide Fireshed Assessment	Existing	USFS(?)
Community Wildfire Protection Plan	Existing	Fire Safe Council
South Shore EA	Winter 2007	USFS

6. Stream Channel SCG Specifics

Stream channels contribute roughly one quarter of the total fine sediment load to Lake Tahoe. Estimates calculated by Simon (2006) during Phase I of the TMDL indicate that fine sediment from streambanks in just five watersheds comprise 93.2 percent of the Basin-wide total load (Tables 6-1 and 6-2). The watersheds with largest fine sediment loads include two streams (Upper Truckee and Blackwood) that have a large streambank component, while others with moderately high total loads and fluxes, have varied contributions from uplands versus streambanks (i.e., Ward, Third, Trout). The Stream Channel SCG will focus its approach on modeling potential sediment load reductions on the three or four largest source streams. These stream system wide analyses will inform an extrapolation to additional streams within the Lake Tahoe Basin for a Basin-wide potential load reduction from projects to reduce pollutant loading from stream channel erosion.

6.1. Source Discussion

The Stream Channel SCG used recent research completed as part of the TMDL Phase 1 effort (Simon et al., 2003 and Simon 2006) that describes and quantifies the stream channel sediment loadings/flux to Lake Tahoe. Simon (2006) quantified fine sediment loadings for each of the 63 contributing watersheds based on prior studies and data on flow, suspended sediment, and channel characteristics of tributaries (Jorgensen et al. 1989; Hill et al., 1990; Noland and Hill 1991; Rowe et al, 1992; Simon et al. 2003; and Rabidoux, 2005).

The primary focus of the Stream Channel SCG will be fine sediment (variously considered <0.063mm 'silts and clays' and <0.020mm 'clays') from streambank erosion, which Phase 1 studies have calculated to represent about 25 percent of the total fine sediment loading to Lake Tahoe (Table 6-1). Other aspects of stream channel erosion (bed erosion, nutrient loading) will also be evaluated, but the relative magnitude of streambank sources will guide the investigation.

Table 6-1. Watersheds with Largest Total and Streambank Fine Sediment (<0.063mm) Loads (T/y) to Lake Tahoe

Watershed[1,2]	Fine sediment load (T/y)[1]	Percent of total fine sediment load (%)	Streambank fine sediment load (T/y)[2]	Percent of total streambank fine sediment load (%)
Upper Truckee River	1,010	19.4	639	49.0
Blackwood Creek	846	16.2	431	33.0
Trout Creek	462	8.9	10.9	0.8
Ward Creek	412	7.9	104	8.0
Third Creek	318	6.1	30.8	2.4
Mill Creek	218.8	4.2	0.4	0.0
Taylor	210	4.0	3.8	0.3
Marlette Creek	199.2	3.8	18.8	1.4

Watershed[1,2]	Fine sediment load (T/y)[1]	Percent of total fine sediment load (%)	Streambank fine sediment load (T/y)[2]	Percent of total streambank fine sediment load (%)
Meeks Creek	73.8	1.4	13.1	1.0
General Creek	53.3	1.0	23.9	1.8
Total of all 63 watersheds	5,206	100.0	1,305	100.0

Source: Simon (2006)
[1] List includes all watersheds with 100T/y or more of fine sediment
[2] List includes all watersheds with 10 T/y or more fine sediment from streambanks

Table 6-2. Watersheds with Largest Fine Particle (0.5 to 20um) Flux (# /year) to Lake Tahoe

Watershed[1]	Fine particle flux (n/y)*	Percent of total fine particle flux (%)
Upper Truckee River	1.93E+19	24.8
Blackwood Creek	5.44E+18	7.0
Ward Creek	4.56E+18	5.9
Trout Creek	4.18E+18	5.4
Third Creek	3.37E+18	4.3
Tahoe Vista	2.69E+18	3.5
Mill Creek	2.57E+18	3.3
Burton	2.43E+18	3.1
Marlette	2.34E+18	3.0
Total of all 63 watersheds	7.79E+19	100.0

Source: Simon (2006)
[1]List includes all watersheds with 2.33E+18 n/y or more of fine sediment

The assessment will build on the knowledge base of TMDL Phase 1 findings regarding the location and magnitude of fine sediment sources from stream channels. Contributors will also apply knowledge from other on-going research and project-related studies, implementation experience, and monitoring results.

6.2. Initial Evaluation of PCOs

The SCG has compiled an initial list of stream erosion PCOs covering the full range of site-specific streambank treatments through comprehensive process-based ecosystem restoration (Table 6-3). The potential PCOs are described with terminology and categories as consistent as possible with national river engineering and stream restoration practices, while reflecting stream and wetland restoration projects in the Lake Tahoe Basin and strategies identified by the Pathway TWGs. The preliminary PCO list will be refined with input from the SCG Contributors as analysis and modeling proceeds.

Load Reduction Quantification

There is a general lack of quantitative information in scientific literature predicting performance of stream channel PCOs, either as individual elements or when combined in treatments. An indication of how the load reduction potential of each PCO may be quantified in this study is listed in Table 6-3. For some PCOs, such as direct bank and/or grade control, quantitative load reduction estimates could be based on standard engineering design performance guidelines. Other PCOs, or grouped PCOs, that are similar to previously implemented projects could have load reduction estimated by empirical data from monitored projects. Long-term water quality and ecosystem monitoring have increased (Palmer et al. 2005), but there is still limited guidance for expected effectiveness of PCOs from empirical data and it is difficult to extrapolate empirical performance between regions and even from stream to stream within regions. Therefore, potential load reduction from many of the identified PCOs or groups of PCOs will be quantified using the CONservational Channel Evolution and Pollutant Transport System (CONCEPTS) model. Each of the applicable methods of quantification is listed for all the identified PCOs (Table 6-3).

Viability

Each PCO has been placed into one of three viabillity categories (High, Medium, Low) based on the SCG Lead's professional experience. "High" viability is used to describe PCOs that are well-defined, are already a standard stream engineering practice, have high performance certainty, and are appropriate at either a site-specific or reach scale. "Moderate" viability is used to describe PCOs that are reasonably defined, have medium to high performance certainty, are accepted (if not a standard stream engineering practice), but are less appropriate at reach scale (i.e., feasible only for site-specific use or must be used in combination with other PCOs to be effective). "Low" viability is used to describe PCOs that have varied characteristics, have low performance certainty, or lack established design standards, but may be applied at site-specific or reach scales. The low viability PCOs may be variations or sub-sets of other more readily defined and analyzed PCOs. PCOs that have low viability are not expected to be major components of MTLR treatment options, but may be included in specific locations and/or land use and transect settings.

Table 6-3. Assessment of PCOs for Stream Erosion Sources of Fine Sediments and Nutrients

Identified PCO[1]	Specific PCOs/Strategies[1]	Load Reduction Quantification	Degree of Viability
Peak flow and duration management	▪ Manage flows (with on- or off- channel storage and releases) ▪ Restore in-stream hydrologic characteristics ▪ Constructed wetlands ▪ Various land management practices to preserve hydrology	▪ Empirical ▪ Modeling	Moderate
Tributary/outfall treatments	▪ Modify local hydraulics to reduce shear stress	▪ Standards	Moderate
Streamside land use buffers	▪ Prevent vegetation removal and/or soil compaction along streambanks ▪ Alleviate compacted soils ▪ Increase SEZ setbacks ▪ Remove recreation activities ▪ Designate riparian conservation areas ▪ Transfer development from SEZs ▪ Buyout coverage and relocate SEZ properties;	▪ Empirical	High
Floodplain constriction / fill removal	▪ Restore floodplain area ▪ Transfer development from SEZs ▪ Buyout and relocation of SEZ properties ▪ Impervious coverage removal in SEZs and setbacks ▪ Remove earthfill and other structures confining flow in channel	▪ Empirical ▪ Modeling	High
Channel constriction removal	▪ Replace outdated, under-sized culverts and/or bridges	▪ Empirical ▪ Modeling	High

Identified PCO[1]	Specific PCOs/Strategies[1]	Load Reduction Quantification	Degree of Viability
Bank Protection-stone	▪ Streambank stabilization (rigid)	▪ Standards ▪ Empirical ▪ Modeling	High
Bank Protection-flexible geotech mattresses	▪ Streambank stabilization (flexible)	▪ Standards ▪ Empirical ▪ Modeling	High
Bank Protection-LWD / rootwad revetment	▪ Streambank stabilization (Anchored LWD) ▪ Restore woody debris assemblages	▪ Empirical	Moderate
Bank Protection-anchored shrub/brush revetment	▪ Streambank stabilization (Anchored shrub)	▪ Empirical	Moderate
Bank Protection- stacked sod revetment	▪ Streambank stabilization (Anchored sod)	▪ Empirical	Low
Bank Strengthening- wet meadow vegetation	▪ Restore streambank vegetation herbaceous (via soil improvements, soil moisture increases) wet meadow 'sod' growing on banks	▪ Empirical ▪ Modeling	Low
Bank Strengthening- woody riparian vegetation	▪ Restore streambank vegetation woody (via soil improvements, soil moisture or stream dynamics-seed beds)	▪ Empirical ▪ Modeling	Low
Grade Control Structure- non porous material	▪ Keyed sheet pile/concrete sills, etc.	▪ Standards ▪ Empirical ▪ Modeling	Moderate
Grade Control Structure- porous rock material	▪ Keyed boulder/cobble wiers, riffles, etc.	▪ Standards ▪ Empirical ▪ Modeling	Moderate
Grade Control Structure- porous rock and LWD	▪ Keyed boulder/LWD jams ▪ Restore woody debris assemblages	▪ Empirical ▪ Modeling	Low
Channel fill with bank toe stabilization	▪ Maintain hydrologic connectivity in streams, meadows, and wetlands ▪ Raise streambed elevation within incised channel	▪ Empirical ▪ Modeling	Low
Bank lowering +floodplain excavation	▪ Maintain hydrologic connectivity in streams, meadows, and wetlands ▪ Excavate bank to create connected active floodplain	▪ Empirical ▪ Modeling	Moderate
Bank lowering +angle reduction	▪ Maintain hydrologic connectivity in streams, meadows, and wetlands ▪ Excavate and contour bank to reduce angle and/or improve bank vegetation	▪ Empirical ▪ Modeling	Moderate
Channel reconstruction	▪ Restore natural geomorphic characteristics through construction ▪ Restore sinuosity to channelized streams ▪ Maintain hydrologic connectivity in streams, meadows, and wetlands	▪ Standards ▪ Empirical ▪ Modeling	High
Channel restoration	▪ Restore natural geomorphic characteristics through construction and restored processes ▪ Restore sinuosity to channelized streams ▪ Maintain hydrologic connectivity in streams, meadows, and wetlands	▪ Empirical ▪ Modeling	Low

[1]PCOs identified by SCG Lead, Contributors, and/or Pathway Forum

PCO Packages

Stream erosion controls can be viewed in terms of approach (passive or active), method (direct or indirect), spatial scale (site-specific to system-wide), intensity (modify processes to reconstruct forms), and scope (satisfying single or multiple objective). These categories may be useful for packaging and evaluating potential PCOs and are described in Appendix B.

Nearly all of the stream erosion PCOs can be applied as site-specific treatments, but they will most likely be applied in combinations at the reach scale to achieve the MTLR. In general, several PCOs may be selected to form a channel "rehabilitation," "naturalization," or "restoration" project. Reach scale treatment that occurs in place (vertically and laterally) would most likely be considered rehabilitation, while reach scale treatment that alters the planform, length, sinuosity, and slope of a stream would be reconstruction or restoration.

Load-related Evaluation Parameters

The load-related PCO performance evaluation, to be performed via standards, empirical, and modeling methods described above, will address parameters that are directly linked to expected fine sediment loads and flux from stream channels (Table 6-4). The parameters and units will be revised with Contributor input and refined to create units consistent with other SCGs and with the modeling output.

Table 6-4. Load Reduction Evaluation Parameters

Load Reduction Factor	Parameter (s)	Evaluation Units
Sediment source reduction	▪ Decreased active bank fine sediment supply ▪ Decreased bank height/length ▪ Stabilization of fines in place ▪ Relocation of active channel away from bank	▪ Length, volume or loads disconnected from channel erosion
Sediment erosion reduction	▪ Improved bank strength parameters	▪ Increase cover and rooting depths ▪ Change in particle size/ critical shear stress ▪ Change cohesion, friction angle, or pore water
Sediment erosion reduction	▪ Reduced channel incision/bank undercutting	▪ Decrease velocity; shear stress and/or resistance
Sediment transport reduction	▪ Improved floodplain connectivity	▪ Increase overbanking for given Q ▪ Net sedimentation on floodplains
Sediment transport reduction	▪ Decreased fine suspended sediment in water column	▪ % or # of TSS or fine TSS change
Spatial scale of treatment	▪ Functionality at site scale	▪ Good to poor ranking 1<>5
Spatial scale of treatment	▪ Functionality at reach scale	▪ Good to poor ranking 1<>5
Constructability/Feasibility	▪ Materials ▪ Methods ▪ Equipment ▪ Staging ▪ Phasing	▪ Good to poor (1<>3) ▪ Typical/Standard Practice ▪ Unusual/Difficult ▪ Experimental/Untested

The non-load related PCO performance evaluation will address other common evaluation parameters including cost and effectiveness certainty, using parameters consistent with other SCGs and units specific for stream channel PCOs.

6.3. Stream-Scale Evaluation Approach

The Stream Channel SCG approach will use recent data regarding the distribution and magnitude of fine sediment sources to Lake Tahoe (Simon 2006) to focus the quantitative analyses on key watersheds that represent over 90 percent of the Basin-wide load. Therefore, the stream-scale analysis will focus on four major/representative watersheds using the CONCEPTS model, rather than smaller, site-specific evaluation of specific PCOs. The approach is essentially Basin-wide in contrast to the Forested Upland, Urban Upland, and Groundwater SCGs, but requires detailed coordination and iteration between the literature/empirical-based and modeling evaluations. Since the four key watersheds identified as major sources are large and varied, it is likely that a range of land use/transect types will be included and be used to assist with the extrapolation step.

The CONCEPTS model (Langendoen 2000; Langendoen et al. 2001) will be used to simulate channel processes and quantify sediment pollutant loads for four key watersheds—Upper Truckee, Blackwood, Ward, and Rosewood (within Third Creek basin)—that represent a little over 92 percent of the total fine sediment streambank load to Lake Tahoe (Simon 2006). Model runs will be performed by and under the direction of scientists at the U.S. Department of Agriculture (USDA) Agricultural Research Service's National Sedimentation Lab in Oxford, MS.

An interface between the LSPC watershed model and CONCEPTS model will be established by the lead modelers (J. Riverson and E. Langendoen). The LSPC watershed models for the four key watersheds will be updated and modified to provide more spatial detail for reach breaks and tributary flow and sediment inputs suitable for the CONCEPTS modeling.

The CONCEPTS model for each of the four key watersheds will be updated and populated as needed using all available topographic and geotechnical data, and validation runs will be made for each stream to demonstrate acceptable calibration to known channel morphology and water quality data.

The SCG will create long-term simulation runs using CONCEPTS that identify differences between loads under existing conditions and the MTLR treatment options.

Analysis by the SCG Lead and Contributors will provide input to the MTLR modeling, including:

1. Land use type and density associated with LSPC subwatersheds that have been updated to link with CONCEPTS would be reviewed to identify the transect types represented in the four key watersheds;
2. Recent watershed assessments and the newly published NRCS soil survey (Loftis 2006) will be used to supplement spatial information about fine sediment sources along stream corridors in the four key watersheds and clarify the relative importance of upland versus streambank sources.
3. Any geographic locations within the four key watersheds determined to be 'untreatable' due to extreme natural or human constraints would potentially be excluded from the MTLR PCOs.
4. Based on initial (standards/empirical-based) effectiveness, the best PCOs suitable to the source site conditions would be assigned by site, reach, and/or watershed (as appropriate) to form the MTLR options.
5. The SCG will assist with parameterizing selected PCOs for representation in the CONCEPTS model.

Model results will be summarized at watershed, reach, or transect scales and will be used to refine initial PCO effectiveness ratings developed in the semi-quantitative analysis prior to any extrapolation.

Additional model runs for sensitivity analysis regarding PCO effectiveness and/or variations from MTLR to better represent more 'practical' PCO options may be conducted as time and budget permit. Otherwise, uncertainty related to these issues would be assessed outside of the modeling effort.

Model results will provide direct estimates of fine sediment load reduction for the four key watersheds. These data will be used along with estimates of approximate amounts of nitrogen and phosphorus in the fine sediment (e.g., data from NRCS 2006) to form nutrient load reduction estimates for the four key watersheds. Some working assumptions that will be refined during the analysis are that nitrogen and phosphorus in streambank sediments are primarily associated with organic and fine particles in the upper banks. Coarser, underlying sands and gravels may contain a significant fraction of total phosphorus in granitic apatite, but it would not be considered biologically available.

6.4. Basin-wide Load Reduction Extrapolation

Quantitative modeling of the four key watersheds is expected to represent the load reduction potential for most (more than 90 percent) of the stream channel sources Basin-wide. However, an effort will be made to extrapolate modeling results to the other high sediment-yielding watersheds (Tables 6-1 and 6-2) so that more than 97 percent of the fine sediment sources from stream channels in the entire Basin would be addressed.

The same criteria for determining land use/transect types, treatable reaches, and MTLR would be applied to the "un-modeled" top ten watersheds. Fine sediment load reductions would be calculated for all treatable reaches by factoring the fine sediment source magnitude of each treated length to reflect the PCO effectiveness rating for assigned PCOs using a combination of direct model results and results scaled to represent the transect type or other variables that prove sensitive during modeling.

All modeling and extrapolation results will be compiled to prepare the Basin-wide draft load reduction estimates, carrying forward uncertainty ratings as needed. The SCG anticipates that uncertainty will be represented by three categories:

- High uncertainty—greater than a factor of two
- Medium uncertainty—within ± 100 percent
- Low uncertainty—within ± 50 percent

6.5. SCG and Review Group Membership and Expertise

Virginia Mahacek, principal of Valley & Mountain Consulting, will serve as group lead and coordinate the technical work, communicate with identified experts (Contributors) participating in various capacities, define the process for evaluating PCOs, and lead report preparation of findings.

The Contributors (Table 6-5) and reviewers (Table 6-6) are geomorphologists, hydrologists and engineers spanning a cross-section of scientific experts and practicing restoration consultants.

Table 6-5. Stream Channel SCG Membership and Expertise

Person	Role	Affiliation	Expertise
Virginia Mahacek	Lead	Valley & Mountain Consulting	Consulting Geomorphologist, Valley & Mountain Consulting. More than 20 years of experience in watershed hydrology, stream geomorphology, river and wetland restoration assessment, design, and environmental impact evaluation. More than 10 years of experience in the Lake Tahoe Basin.
Dr. Andrew Simon	Contributor Principal Investigator-CONCEPTS modeling	USDA Agricultural Research Service-National Sedimentation Laboratory	Research Geologist, USDA Agricultural Research Service, National Sedimentation Laboratory. More than 20 years of experience in fluvial geomorphology, channel evolution, sediment transport and bank-erosion evaluation and modeling. Four years of experience in the Lake Tahoe Basin.
Dr. Eddy Langendoen	Contributor Lead Modeler-CONCEPTS	USDA Agricultural Research Service-National Sedimentation Laboratory	Research Hydraulic Engineer, USDA Agricultural Research Service, National Sedimentation Laboratory. More than 15 years of experience in sediment transport mechanics, channel evolution and computational hydraulics. Lead author of CONCEPTS modeling tool. Four years of experience in the Lake Tahoe Basin.
Mike Rudd, P.E.	Contributor	ENTRIX, Inc.	Consulting Civil Engineer, ENTRIX, Inc. More than 15 years of experience in civil design, remediation evaluation/design, and construction. More than 10 years focused on wetland and river stabilization/ restoration. More than 10 years of experience in the Lake Tahoe Basin.
Mitchell Swanson	Contributor	Swanson Hydrology+ Geomorphology	Consulting Hydrologist/Geomorphologist, Swanson Hydrology+Geomorphology. More than 20 years of experience in hydrology, hydraulic studies, and geomorphology relating to restoration and management. More than 15 years of experience in the Lake Tahoe Basin.

Table 6-6. Stream Channel Review Group Members and Expertise

Person	Perspective	Affiliation
Craig Oehrli	Restoration Project Management, Monitoring	USFS, UTRWAG
Cyndie Walck	Monitoring, Restoration	CA Parks, UTRWAG
Scott Carroll	Project Management & Funding	CTC, UTRWAG
Jennifer Quickel	Restoration Project Management	CSLT, UTRWAG
Liz Harrison	Public Lands Restoration	NDSL, Soils TWG
Peter Maholland	Public Lands Restoration	NV Division of State Parks
Kim Gorman	TMDL	Tahoe TMDL Team, UTRWAG Liaison
Tim Rowe	Hydrology, Monitoring & Science	USGS, Hydrologist Lake Tahoe Basin Liaison
Dr. G. Mathias Kondolf	Geomorphologist-Project Evaluation/Monitoring	UC Berkeley

7. Glossary

Integrated Water Quality Management Strategy – a plan to help stakeholders to understand ways in which the TMDL load reductions could be achieved using treatment options from all of the major pollutant source categories.

IWQMS Alternative – a bundle of treatment options that includes treatment options from all SCGs. The 5-10 IWQMS Alternatives will be presented to stakeholder groups for comment and then a preferred IWQMS will be selected.

Pathway Transect – a conceptual tool to describe the combinations of land uses that are expected within the Lake Tahoe Basin. They present a gradient of development that can help reviewers understand the types of treatment options that will be used in a particular area.

Pollutant control option (PCO) – a general term to describe any potential method to reduce or control pollutants of concern. All Best Management Practices (BMPs) are PCOs, but the converse is not true. Combinations of BMPs (including non-structural) can be referred to as a PCO.

Setting – general land use and physical characteristics of an area based initially on Pathway Transects. Settings often determine which PCOs are applicable to an area.

Treatment Options – a combination of PCOs that are selected to work together in a specific setting. Treatment options were sometimes called “PCO packages” within previous project documents.
Current Practice – a set of techniques or pollutant controlls which have been commonly applied to areas of Lake Tahoe.

Draft
Lake Tahoe TMDL
Source Category Group
Work Plan

Appendices for
Air Deposition &
Stream Channel Erosion
Source Category Groups

December 15, 2006

California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, California 96150

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Appendix A. Summary of Current Knowledge and General Review of PCOs for Atmospheric Deposition

A.1. What We Know about Atmospheric Deposition vis a vis Lake Tahoe

Local Versus Regional Sources of Atmospheric Pollutants Affecting Lake Clarity

Recent studies indicate that the pollutants most closely connected to the decline in Lake Tahoe's clarity largely originate from within the Basin with some unquantified portion from sources outside the Basin. Possible out of Basin sources include transported Asian dust, transported Sacramento Valley dust, and forest fire smoke. Large particles have less residence time in the atmosphere than smaller particles. Thus, large particles are generally of local origin, whereas fine particles less than 2.5 µm diameter may originate from outside the air Basin.

UC Davis has found that most of the phosphorus measured in the air in the Lake Tahoe area during the winter and summer is between 2.5 and 35 µm in diameter, consistent with sources being resuspended road dust and soil. This implies that most of the phosphorus comes from in-Basin sources, since particles in this size range are rarely transported far in the atmosphere (Gertler et al., California Agriculture, April-June, 2006).

Professor Tom Cahill of UC Davis concludes that all of the NO_x as well as most of the particles above 2.5 µm in diameter are derived from sources within the air Basin. Cahill concludes that particles below 2.5 µm in diameter tend to be of local origin during the winter but only 50 percent of local origin in the summer with the remaining 50 percent from regional sources outside the Basin (Cahill and Cliff, *Air Quality in the Lake Tahoe Watershed Assessment*, 2000).

CARB's deposition estimates for 2003 (CARB, LTADS Final Report, August 2006) suggest that local sources account for 60 percent - 81 percent of the nitrogen, 53 percent - 79 percent of the phosphorus, and 67 percent - 85 percent of the PM deposited to the lake by wet deposition.

According to CARB's LTADS Final Report, there is insufficient information to apportion with any certainty the ammonia between local and regional sources. Based on observed concentrations, atmospheric lifetimes, and transport patterns, CARB concluded that nitric acid deposited to the Lake must be primarily of local origin.

Atmospheric Deposition

Recent estimates indicate that atmospheric deposition accounts for 51 percent of the annual nitrogen load, 16 percent of the annual phosphorus load, and 9 percent of the annual fine sediment load into the lake (Lake Tahoe TMDL Phase 1 Report, 2006). CARB calculated dry deposition for each chemical specie of interest (gas or particle) as the product of the measured concentration of the specie multiplied by the theoretical size-dependent deposition velocity for that specie (CARB, LTADS Final Report, August 2006). For phosphorus, CARB assumed an ambient concentration of 40 ng/m^3. CARB estimated wet deposition for each chemical specie of interest based on first principles, and assumed that locally generated pollutants are represented by the removal of pollutants in a column of air extending from the lake surface to 700 meters above the lake surface, whereas the transport component of wet deposition is represented by the washout of regional pollutants in a layer of air extending from 700 meters above the lake surface to 3,000 meters above the lake surface.

CARB's estimates of atmospheric deposition into the lake are based on a single one-year monitoring program in 2003. CARB's deposition estimates assume:

- modest depletion in concentrations of PM and phosphorus over the Lake compared to concentrations observed at the urban monitoring sites
- dry deposition occurring during all periods, including those with precipitation
- assignment of 25 µm as the upper boundary for the size of large particles to represent the worse case condition at the shoreline of the lake
- washout efficiency ranging from 50 percent to 100 percent
- precipitation amounts measured on shore are applicable for the entire lake

CARB's deposition estimates for 2003 suggest that:

- dry deposition accounts for 30 percent - 50 percent of the NH_4^+, 26 percent - 50 percent of the NO_3^-, 63 percent - 81 percent of the NH_3, 62 percent - 82 percent of the HNO_3, 53 percent - 73 percent of the total N, 26 percent - 33 percent of the phosphorus, and 33 percent - 52 percent of the PM (i.e., TSP) deposited to the lake each year by dry plus wet deposition
- dry deposition accounts for 7 percent - 26 percent of the fine PM, 25 percent - 42 percent of the coarse PM, and 71 percent - 85 percent of the large PM deposited to the lake each year by dry plus wet deposition

CARB's final LTADS report (2006) states that nitrogen is deposited to Lake Tahoe primarily in the form of ammonia gas and secondarily in the form of nitric acid. Aerosol species of nitrogen (ammonium and nitrate ions) are smaller contributors to atmospheric deposition of total nitrogen in the Tahoe Basin. CARB has made estimates of the atmospheric deposition of fine sediments (basically fugitive soil dust) to the lake based on land-based measurements. It is critical that direct measurements of fugitive dust be made over the lake. Professor Cahill has proposed these types of measurements in a grant proposal submitted to the US EPA.

UC Davis' bucket measurements of wet and dry deposition indicate that dry deposition of nitrogen species and phosphorus account for about 70 percent and 50 percent, respectively, of the total wet plus dry deposition to the Lake.

Lake Clarity

UC Davis' water clarity model indicates that the clarity of Lake Tahoe is dominated by scattering and absorption of light by inert soil particles in the 0.5 to 5 µm size range. Soluble species such as sulfates and nitrates have no "residual" optical effect. Insoluble organics with a refractive index close to that of water are optically unimportant. It should be pointed out that the model does not consider the potential impact from "black" elemental carbon particles.

Lake Tahoe Air Basin Emission Inventory

CARB's emission inventory for the Lake Tahoe Air Basin has the following problems:

- poorly documented
- does not properly account for off-road sources
- does not use Basin-specific parameters for emission factor equations
- does not use Lake Tahoe Basin-specific source activities
- does not include the Nevada portion of the air Basin
- uses outdated PM2.5/PM10 fractions for fugitive dust sources

Thus, identifying and ranking atmospheric sources of pollutants that deposit directly to Lake Tahoe is imprecise. CARB's inventory is insufficient at this time to allow us to accurately quantify the effect of control measures. Furthermore, PM emission inventories do not include secondarily generated PM species that are formed in the atmosphere such as ammonium nitrate which can contribute significantly to ambient PM concentrations (primarily below 2.5 μm in diameter). Ammonium nitrate will dissolve in the Lake and will serves as a nutrient for algae growth resulting in decreased clarity.

The 2004 emission inventory for the California portion of the Lake Tahoe Basin included in CARB's Final LTADS Report is reproduced in Figure 1. For each of eight pollutant species, Figure 1 lists the total emissions (tons/day) from sources within the Basin and breaks out the percentage of those emissions from each of 10 source categories. As in many other air basins, mobile sources are a major source category for reactive organic gases (ROG), carbon monoxide (CO), and oxides of nitrogen (NO_X), NH_3, and PM.

Mobile sources accounted for ~90 percent of the NO_x emissions, whereas area sources of fugitive dust (primarily resuspended soils) accounted for ~67 percent of the TSP, ~53 percent of the PM10, and only about 13 percent of the PM2.5 emissions. Note: The PM2.5 emissions for area sources of fugitive dust shown in Figure A-1 are too high by a factor of 2 based on controlled laboratory experiments conducted by Midwest Research Institute (MRI) in 2005 for the Western Regional Air Partnership (WRAP). The revised PM2.5/PM10 ratios for these fugitive dust source categories were adopted by the U.S. EPA in July 2006. Residential wood combustion accounted for ~23 percent of the TSP, ~33 percent of the PM10, and ~74 percent of the PM2.5 emissions. Wildfires, considered a natural source, account for a negligible fraction of the total Basin NO_x and PM emissions.

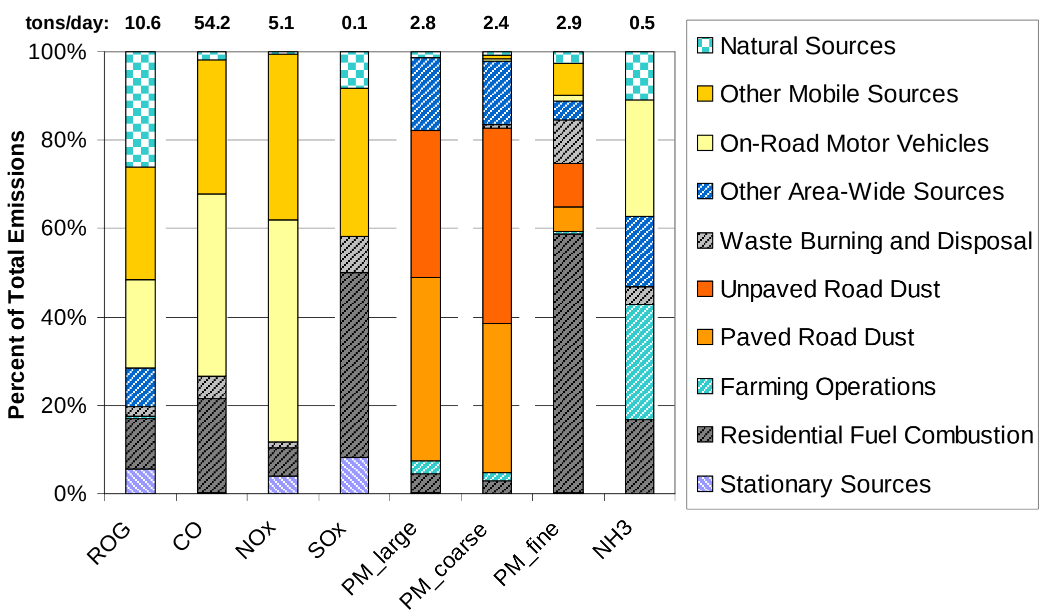

Figure A-1. 2004 Emission Inventory for the CA Portion of the Lake Tahoe Air Basin

Fine Sediments

To a first approximation, fine sediments of atmospheric origin can be equated to fugitive dust of geological origin in the total suspended particulate (TSP) size range (i.e., particles with diameters less than ~ 30 µm). There are other sources of TSP included in Figure 1 (e.g. residential fuel combustion, managed waste burning, mobile sources) that are not of geological origin and thus do not contribute to the atmospheric deposition of fine sediments. The chemical composition of the TSP emissions from these other sources is predominantly organic and elemental carbon.

CARB's 2005 emission inventory for fugitive dust of geological origin in the TSP size range for the CA portion of the Lake Tahoe Air Basin is presented in Table 1. To a first approximation, one can scale these emission estimates to the entire Lake Tahoe Air Basin by multiplying both the paved and unpaved road dust emissions by 1.52 to account for the difference in VMT between the CA and NV portions of the Lake Tahoe Air Basin, and by multiplying the emissions for the other source categories by a factor of 1.31 to account for the difference in population between the CA and NV portions of the Lake Tahoe Air Basin (Reference: DRI Final Report to CARB for Contract No. 01-734, Oct. 22, 2004). This exercise produces an estimate of 8.26 tons/day or 3,015 tons/year of fugitive geological soil dust emissions. Based on the pollutant budget for Lake Tahoe that indicates that atmospheric deposition accounts for 1,400 metric tons of fine sediments being depositing into the lake each year (i.e., 1,540 tons/year), these results suggest that approximately 50 percent of the annual fugitive geological soil dust emissions from the entire Lake Tahoe Air Basin are deposited to the lake. This may not be realistic and will be checked with rough calculations**.** Either the emission inventory is too low or the atmospheric deposition pollutant budget is too high, or both the emission inventory and the atmospheric deposition pollutant budget are incorrect.

Table A-1. 2005 Fugitive TSP Dust Emission Inventory for the Lake Tahoe Air Basin

	CA Portion	CA & NV Portion	
SOURCE CATEGORY	TSP (Tons/day)	TSP (Tons/day)	percent of total TSP
Farming Operations	0.13	0.17	2
Construction & Demolition	0.86	1.13	14
Paved Road Dust	2.22	3.37	41
Unpaved Road Dust	2.33	3.54	43
Fugitive Windblown Dust	0.04	0.05-	<1
TOTAL	5.58	8.26	

The major sources of fugitive geological soil dust emissions in descending order of percent contribution are unpaved road dust (43 percent), paved road dust (41 percent), construction and demolition (14 percent), farming operations (2 percent), and windblown dust (<1 percent). Due to the inherent problems of this inventory (see discussion above), the absolute emission rates are not correct. However, the relative contribution of each of the different source categories shown in Table 1 is probably correct.

Controlling sources of fugitive dust with high phosphorus content will simultaneously reduce both fine sediment load and phosphorus load into the lake.

In their LTADS final report, CARB concluded that road dust is the dominant source of particulate matter (PM) concentrations at LTADS monitoring sites and in the immediate vicinity of the Lake, as inferred both from ambient concentrations and special source-oriented monitoring results. Road dust as the dominant source of PM is consistent with the inventory estimates of PM_coarse and PM_large provided in the current Lake Tahoe Air Basin emission inventory.

The location and timing of emissions is important to determining their potential for deposition to the Lake. Sources located near the Lake and at low altitude have much greater potential for deposition to the Lake than more distant sources. In general, emissions released during nighttime or early morning hours will have much greater potential for impacting the Lake than emissions occurring during morning through afternoon. Thus the greatest potential for reducing deposition to the Lake would be through reducing emissions released near and immediately upwind of the Lake. Due to the typical daily cycle of wind directions, reductions in emissions during late afternoon through mid morning would have more benefit than reducing emissions at mid-day or early afternoon. Similarly, reducing emissions that are released near ground level would be relatively more effective than reducing emissions released at altitude.

Phosphorus

CARB's measurements of phosphorus in 2003 from the LTADS project have the following problems: (a) most ambient measurements collected in the Lake Tahoe Air Basin are below detection level, and (b) there is a large uncertainty in the XRF measurements of phosphorus due to the uncertainty of the self-absorption correction factors and possible interferences from Si and S.

Based on CARB's chemical profiles, residential wood combustion (RWC) and campfires are not major sources of phosphorus. However, wildfires and prescribed fires occurring within the Lake Tahoe Air Basin as well as outside the Lake Tahoe Air Basin are potential sources of phosphorus. It needs to be pointed out that the chemical profiles of source samples have a large variability as well as the same analytical problems associated with XRF measurements of phosphorus discussed above. UC Davis observed a significant reduction in ambient phosphorus concentrations after CALTRANS switched from using volcanic cinders to sand as an abrasive applied to paved roads for better vehicle traction on ice- and snow-covered roads (T. Cahill, private communication, Sept. 6, 2006). The phosphorus content (i.e., weight percent) for different sources as a function of particle size is given in Table A-2.

Table A-2. CARB's Phosphorus PM Source Profiles

WEIGHT % of TSP	***WEIGHT % of PM 10***	***WEIGHT % of PM 2.5***	***PM PROFILE NAME***
0.7532	1.0695	0.8142	livestock operations dust
0.2723	0.2723	0.2723	PAVED ROAD DUST*
0.1602	0.1944	0.1997	windblown dust-unpaved rd/area
0.1499	0.1979	0.2273	CONSTRUCTION DUST
0.1499	0.1979	0.2273	landfill dust
0.1250	0.1250	0.1250	tire wear
0.1249	0.1679	0.1975	agricultural tilling dust
0.1249	0.1679	0.1975	windblown dust-agricultural lands
0.1096	0.1096	0.1096	UNPAVED ROAD DUST
0.0301	0.0301	0.0215	agricultural burning - field crops
0.0301	0.0301	0.0215	weed abatement burning
0.0295	0.0295	0.0205	grass/woodland fires
0.0295	0.0295	0.0205	open burning
0.0295	0.0295	0.0205	range improvement burning
0.0295	0.0295	0.0205	WASTE BURNING
0.0288	0.0288	0.0196	orchard prunings burning
0.0199	0.0199	0.0098	forest management burning
0.0199	0.0199	0.0098	timber and brush fires
0.0123	0.0127	0.0056	diesel vehicle exhaust
0.0000	0.0000	0.0000	brake wear
0.0000	0.0000	0.0000	FIREPLACES AND WOODSTOVES

* Official paved road dust factor; removal of an outlier data point, results in a P emission factor of 0.1372 for Paved Road Dust.
Note #1**:** These factors (dated 9/27/02) do not include newly discovered, potentially large self absorption correction factors for PM > 2.5 µm.
Note #2**:** Data from Turn et al. (1997), indicate comparable P fractions with pine slash burn (n=4 and 2 samples (Doug fir for PM2.5 & PM10) > uncertainty) P2.5 ~0.0097 and P10 ~0.0200 and fruit tree prunings (n=4 & none > uncertainty) P2.5 ~0.0200 and P10 ~0.0290).
Note #3**:** The PM sources shown in capital letters are the major PM sources in the Lake Tahoe Air Basin.

Combining the results from CARB's 2005 TSP emission inventory for the CA portion of the air basin extrapolated to the entire air basin with the source profile data shown in Table A-2 (i.e., using CARB's official paved road dust source profile) provides an annual phosphorus emissions inventory for the Lake Tahoe Air Basin which is presented in Table A-3. Removing the outlier data point for paved road dust (see footnote to Table A-2) and using the revised P emission factor of 0.1372 for paved roads results in a different phosphorus emissions inventory shown in Table A-4. Comparing the results in Table A-4 with those in Table 3 indicates lower phosphorus emissions from paved roads by a factor of two using the revised P emission factor. However, the relative ranking of sources contributing to phosphorus emissions remains unchanged. The major sources of phosphorus in descending order of percent contribution are paved road dust, unpaved road dust, construction, farming operations, and managed burning.

Table A-3. 2005 Phosphorus Emissions Inventory for Lake Tahoe Air Basin

Source Category	TSP Emissions (tons/year)	Phosphorus/TSP (weight percent)	Phosphorus Emissions (lb/year)	Ranking (percent of Total P Emissions)
Residential Wood Combustion	2.52	0.0000	0	-
Farming Operations	0.17	0.1249	42	4 (1.4 percent)
Construction & Demolition	1.13	0.1499	339	3 (11 percent)

Paved Road Dust	3.37	0.2723	1,835	1 (61 percent)
Unpaved Road Dust	3.54	0.1096	776	2 (26 percent)
Managed Burning	0.42	0.0295	25	5 (0.8 percent)
On-Road Motor Vehicles	0.09	0.0010*	0.2	Negligible
Other Mobile Sources	0.42	0.0123**	10	Negligible
TOTAL	11.66		3,027	

* Assume source profile for gasoline vehicle exhaust for this category (Houcke et al., 1989).
** Assume source profile for diesel vehicle exhaust for this category

Table A-4. Revised 2005 Phosphorus Emissions Inventory for Lake Tahoe Air Basin

Source Category	TSP Emissions (tons/year)	Phosphorus/TSP (weight percent)	Phosphorus Emissions (lb/year)	Ranking (percent of Total P Emissions)
Residential Wood Combustion	2.52	0.0000	0	-
Farming Operations	0.17	0.1249	42	4 (2 percent)
Construction & Demolition	1.13	0.1499	339	3 (16 percent)
Paved Road Dust	3.37	0.1372	925	1 (44 percent)
Unpaved Road Dust	3.54	0.1096	776	2 (37 percent)
Managed Burning	0.42	0.0295	25	5 (1 percent)
On-Road Motor Vehicles	0.09	0.0010*	0.2	Negligible
Other Mobile Sources	0.42	0.0123**	10	Negligible
TOTAL	11.66		2,117	

Cahill et al. (2003) have found that ambient phosphorus concentrations in the winter are strongly correlated with road sanding operations. CARB made no conclusions about sources of phosphorus from their LTADS ambient data. However, the source samples collected prior to and during LTADS indicate that road dust may be the primary source with contributions from the burning of live vegetative material and lubricating oils.

Nitrogen Species

Based on CARB's emission inventory for the CA portion of the Lake Tahoe Air Basin, mobile sources account for approximately 90 percent of NO_x emissions. Thus, mobile sources account for most of nitric acid formed in the atmosphere. According to CARB, the major sources of NH_3 (see Figure 1) in descending order of percent contribution are on-road motor vehicles (27 percent); farming operations (25 percent); residential wood burning (17 percent); biogenic sources (11 percent); waste burning including prescribed burns (3 percent); with the balance (15 percent) attributed to miscellaneous processes.

CARB's breakdown by source category for NO_x emissions for the California portion of the Lake Tahoe Air Basin for 2005 is presented in Table 5. Ranked in decreasing order of contribution to the NO_x emissions, the sources accounting for greater than 5 percent of the annual average daily NO_x emissions are off-road equipment (~23 percent of the total NO_x emissions), commercial shipping (~16 percent), light duty trucks (~12 percent), medium duty and heavy duty gas trucks (each source category accounting for ~9 percent of the total NO_x emissions), residential wood combustion (~6 percent), light duty passenger cars (~6 percent), and recreational boats (~5 percent). With the large inherent uncertainties in the emission inventory, the absolute NO_x emissions for each source category are not accurate, and the relative ranking of the source categories may be different from that presented here.

Table A-5. CARB's 2005 NOx Emission Inventory for CA Portion of Lake Tahoe Air Basin

Source Category	Source	NOx (Tons/day)	Ranking (percent of Total NOx)
Stationary	Fuel Combustion	0.16	(~3 percent)
	Waste Disposal	0.04	(<1 percent)
	Total Stationary Sources	0.20	(~3 percent)
Miscellaneous Processes	Residential Wood Combustion	0.33	6 (~6 percent)
	Managed Burning	0.07	(~1 percent)
	Total Miscellaneous Processes	0.40	(~7 percent)
On-Road Motor Vehicle	Light duty passenger	0.35	6 (~6 percent)
	Light duty gas trucks	0.71	3 (~12 percent)
	Medium duty gas trucks	0.54	4 (~9 percent)
	Heavy duty gas trucks	0.15	(~3 percent)
	Heavy duty diesel trucks	0.53	4 (~9 percent)
	Motorcycles	0.01	(<1 percent)
	Heavy duty diesel urban buses	0.06	(~1 percent)
	Heavy duty gas urban buses	0.02	(<1 percent)
	School buses	0.02	(~1 percent)
	Motor Homes	0.03	(~1 percent)
	Total On-Road Motor Vehicles	2.42	(~42 percent)
Other Mobile Sources	Aircraft	0.19	(~3 percent)
	Commercial shipping	0.93	2 (~16 percent)
	Recreational boats	0.27	8 (~5 percent)
	Off-road recreational vehicles	0.08	(~1 percent)
	Off-road equipment	1.33	1 (~23 percent)
	Total Other Mobile Sources	2.81	(~48 percent)
	Total Mobile Sources	5.24	(~90 percent)
Grand Total		5.83	

Note: Natural wildfires produce an estimated 0.03 tons NO_x/day.

A.2. PCOs for Each Major Source Category

The major atmospheric sources of fine sediments (paved roads, unpaved roads, and construction and demolition, farming operations) are discussed in this section and a list of PCOs for each source category is presented. Then, a list of PCOs for mobile sources, which is the major source of atmospheric nitrogen species, is identified. Finally a list of PCOs for residential wood combustion and managed waste burning, that are minor sources of NO_x, are presented. Controlling fugitive soil dust sources that contain phosphorus will reduce both fine sediment and phosphorus deposition loads to the Lake. Note: Neither the UC Davis's lake clarity model or pollutant budget addresses the impact of atmospheric deposition of carbonaceous particulate species, specifically colored organic compounds and black elemental carbon, generated by combustion sources. This is an area that needs to be addressed.

Paved Roads

Particulate emissions from paved roads originate from material previously deposited on the travel surface, and may result from particle resuspension generated by moving vehicles as well as by the wind. Particulate material deposited on paved roads includes construction mud and dirt carryout, litter, biological debris, erosion of shoulders and adjacent areas, motor vehicle deposits from tires and undercarriages, atmospheric dustfall, pavement wear, and spills.

The quantity of particulate emissions from the resuspension of loose material on the road surface due to vehicle travel on a dry paved road may be estimated using the following empirical expression published in EPA's Compilation of Air Pollutant Emission Factors (AP-42):

$$E = k\left(\frac{sL}{2}\right)^{0.65} \times \left(\frac{W}{3}\right)^{1.5} - C \qquad (1)$$

where, E = particulate emission factor (having units matching the units of k),
k = particle size multiplier for particle size range,
sL = road surface silt loading of material equal to or less than 75 µm (g/m^2),
W = average weight (tons) of the vehicles traveling the road, and
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.
[Note: Values of k and C for TSP, PM0 and PM2.5 are included in AP-42.]

For freeways and major roads with silt loadings typically less than 0.04 g/m^2, the resuspended paved road dust emissions are approximately 10 times the sum of the exhaust, brake wear and tire wear emissions. For collector and local roads with typical silt loadings of 0.32 g/m^2, the resuspended paved road dust emissions are approximately 40 times the sum of the exhaust, brake wear and tire wear emissions.

Because of the importance of road surface silt loading, control techniques for paved roads attempt either to prevent material from being deposited onto the surface (preventive controls) or to remove from the travel lanes any material that has been deposited (mitigative controls). Currently, water suppression (which includes wetting down the street in its simplest form to washing the material off the roadway in the extreme) is utilized as the main method to control fugitive dust emissions from paved roads. Water flushing uses pressurized sprays from a water truck to dislodge road dust and transport it to the curb where much of the particulate is washed into the drain system. A combination of water flushing followed immediately by broom sweeping has been widely used to remove debris from paved roads. Flushing can be expected to reduce resuspension while the road is wet; thus to be effective, water suppression needs to be repeated at frequent intervals (i.e. several times a week) during dry weather.

Other mitigative measures for paved road dust include mechanical broom sweeping and vacuum sweeping. Water droplets are often sprayed onto the road surface prior to sweeping to suppress dust resuspension caused by the sweeper. Mechanical broom sweepers use large rotating brooms to lift the material from the street onto a conveyer belt that is then discharged into a collection hopper. Several sweepers use circular gutter brooms to direct the debris into the path of the rotating broom. Commercially available vacuum sweepers use a gutter broom to loosen dirt and debris from the road surface and direct this material to a vacuum nozzle that sucks it into a hopper. In most cases, mechanical broom sweepers resuspend small particles into the air and vacuum sweepers have achieved widely varying and generally limited degrees of success. Consequently, one also needs to consider preventative measures for paved road dust resuspension. Covering of loads in trucks and the paving of access areas to unpaved lots or construction sites are examples of preventive measures. Reducing the number of vehicles on the road will also reduce paved road dust emissions. The actual control efficiencies for any of these techniques can be highly variable. Locally measured silt loadings before and after the application of controls is the preferred method to evaluate controls. It is particularly important to note that street sweeping of gutters and curb areas may actually increase the silt loading on the traveled portion of the road. Redistribution of loose material onto the travel lanes will actually produce a short-term increase in the emissions.

In general, preventive controls are usually more cost-effective than mitigative controls. The cost-effectiveness of mitigative controls decreases dramatically as the size of an area to be treated increases. The cost-effectiveness of mitigative measures is also unfavorable if only a short period of time is required for the road to return to equilibrium silt loading condition. Because available controls will affect the silt loading, controlled emission factors may be obtained by substituting controlled silt loading values into the appropriate emission factor equation. The collection of surface loading samples from treated, as well as baseline (untreated) roads provides a means to track effectiveness of the controls over time.

CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin that I have extrapolated to the entire air basin indicates that paved road dust accounts for about 41 percent of the fugitive soil dust emissions (with 90 percent of these emissions from major and local streets and the balance from freeways and collector streets), 44 percent to 61 percent of the phosphorus emissions (depending on which paved road dust source profiles are used), and none of the NO_x emissions. A list of PCOs for paved roads for further evaluation include the following preventative measures:

- Switch from the use of anti skid materials such as cinders and sand used for traction on snow/ice-covered roads to deicers
- Designate specific sites for snow removed from roadways rather than the sides of the road to minimize erosion of soil back onto road as the snow melts
- Plant vegetation or install barriers for roads close to the lake for road dust sequestration
- Pave shoulders to minimize mud/dirt carryout to road surface
- Clean gutters and curbs to reduce carryover of material to road surface
- Reduce traffic near lake by moving traffic to roads further inland
- Require trucks hauling soil to use tarps over the load

and the following mitigative measures:

- Implement regular street sweeping program with PM10-efficient vacuum units
- Replace street sweepers with PM10-efficient vacuum units
- Clean up wind- or water-borne deposits as well as spills within 24 hours of discovery
- Remove abrasive, anti-skid material from roadway as soon as the road dries out after a snow storm

Unpaved Roads

As is the case for paved roads, particulate emissions occur whenever a vehicle travels over an unpaved surface. Unlike paved roads, however, the road itself is the source of the emissions rather than any "surface loading". Fine particles are brought up from the road base and the road surface material is pulverized by the force of rolling wheels. Dust is resuspended when it is picked up by the wheels and by the turbulent air currents caused by the passing vehicle.

Travel surfaces may be unpaved for a variety of reasons. Possibly the most common types of unpaved roads are those found in agricultural regions. Farm roads are established to facilitate land operations, cultivation, inspection and harvesting. Paving is impractical because these roads are often very long and may experience only sporadic traffic. Some industrial roads are, by their nature, not suitable for paving. These roads may be used by very heavy vehicles or may be subject to considerable spillage from haul trucks. Other roads may have poorly constructed bases that make paving impractical. Because of the additional maintenance costs associated with a paved road under these service environments, emissions from these roads are usually controlled by regular applications of water or chemical dust suppressants.

For vehicles traveling on unpaved surfaces at industrial sites, PM emissions are estimated from the following empirical equation:

$$E = k\,(s/12)^a\,(W/3)^b \tag{2}$$

and, for vehicles traveling on publicly accessible roads, dominated by light duty vehicles, PM emissions may be estimated from the following equation:

$$E = [k\,(s/12)^a\,(S/30)^d\,/\,(M/0.5)^c] - C \tag{3}$$

where, E = size specific emission factor (lb/VMT)
s = surface material silt content (percent)
W = mean vehicle weight (tons)
M = surface material moisture content (percent)
S = mean vehicle speed (mph)
C = emission factor for 1980’s vehicle fleet exhaust, brake wear and tire wear
k, a, b, c and d are empirical constants given in AP-42.

Emissions from exhaust, brake wear and tire wear (C) are insignificant compared to the resuspended unpaved road dust emissions.

A wide variety of options exist to control emissions from unpaved roads. Options fall into the following three groupings: (a) vehicle restrictions (i.e., source extent reductions) that limit the speed, weight or number of vehicles on the road, (b) surface improvement by measures such as paving or covering the road surface with another material that has a lower silt content such as gravel or slag, and (c) surface treatment that require periodic reapplication such as watering or treatment with chemical dust suppressants. Control measures proposed for this source category are designed to reduce fugitive dust emissions by preventing (1) disturbance of soil by vehicle movement over unpaved areas, and (2) wind and water erosion and dust transport of unprotected soil to the roadways.

Available control options span broad ranges in terms of cost, efficiency, and applicability. For example, traffic controls provide moderate emission reductions (often at little cost) but are difficult to enforce. Although paving is highly effective, its high initial cost is often prohibitive. Furthermore, paving is not feasible for industrial roads subject to very heavy vehicles and/or spillage of material in transport. Watering and chemical suppressants, on the other hand, are potentially applicable to most industrial roads at moderate to low costs. However, these require frequent reapplication to maintain an acceptable level of control. Chemical suppressants are generally more cost-effective than water but not in cases of temporary roads that are common at construction sites. In summary, then, one needs to consider not only the type and volume of traffic on the road but also how long the road will be in service when developing control plans. Unlike surface improvements that are generally a "one-shot" control method, surface treatments require frequent reapplication ranging from hours (or days) for water to several weeks (or months) for chemical dust suppressants.

CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin that I have extrapolated to the entire air basin indicates that unpaved road dust accounted for about43 percent of the fugitive soil dust emissions (with 61 percent of these emissions from BLM roads, 36 percent from City/County roads, and the balance from US Forest/Park roads and farm roads), 31 percent of the phosphorus emissions, and none of the NO_x emissions. A list of PCOs for unpaved roads for further evaluation include:

- Limit maximum speed on unpaved roads to 25 miles per hour
- Limit weight and/or number of vehicles
- Pave unpaved roads and unpaved parking lots
- Apply gravel or slag over unpaved roads and unpaved parking lots
- Implement controls to minimize trackout of unpaved road dust onto paved roads (e.g., pipe-grid system or gravel bed)
- Plant a vegetative cover
- Temporary, permanent and/or seasonal road closures
- Apply water to industrial unpaved roads several times during day-time hours
- Apply chemical dust suppressant annually
- Plant vegetation or install barriers for roads close to the lake for road dust sequestration
- Prohibit new road construction in areas where soil instability is an issue
- Reduce traffic near lake by moving traffic to roads further inland

A combination of these control options may be required to reduce fugitive dust emissions as much as possible. If and when vehicular travel increases to the point that these control options are no longer effective, paving should be considered since it is the most efficient and the only permanent control measure for unpaved roads (and shoulders, parking lots, etc.). Several different paving options are available.

Construction and Demolition

Construction and demolition activities are temporary but important sources of resuspended soil dust. Road and building construction and demolition disturb the landscape and use heavy vehicles that grind geological material into a fine powder. These vehicles often suspend this powder into the air where it is entrained by the wind. Even without vehicular traffic, wind gusts can raise large amounts of material for transport to populated areas. Dust emissions from construction and demolition activities are generated by such activities as land clearing, blasting, ground excavation, cut-and-fill operations, wind erosion of the unprotected soil, and travel on the site and its access roads.

The quantity of dust emissions from construction operations is proportional to the area of land being worked and to the level of construction activity. By analogy to the parameter dependence observed for unpaved roads, one can expect emissions from construction operations to be positively correlated with the silt content of the soil (i.e., particles smaller than 75 µm in diameter), as well as with the speed and weight of the construction vehicle, and to be negatively correlated with the soil moisture content. In addition to dust emissions originating from on-site activities, substantial emissions are possible off-site because of material tracked out from the site and deposited on adjacent paved streets. Because all traffic passing the site (i.e., not just that associated with the construction) can resuspend the deposited material, this "secondary" source of emissions may be far more important than all the dust sources located within the construction site. Furthermore, this secondary source will be present during all construction operations.

Control measures for construction and demolition activities include traditional methods such as watering and wind breaks, as well as work practice related control methods such as wheel washes and phasing activities to minimize the extent of open exposed areas. Wet suppression and wind speed reduction are the two most common methods used to control open dust sources at construction sites because a source of water and material for wind barriers tend to be readily available on a construction site. Dust control plans should contain precautions against watering programs that exacerbate trackout. The amount of water applied depends upon the specific operation, the type of soil at the site, and the site's exposure to wind. Trucks transporting soil to or from the site should use a tarp covering the load to avoid loss of soil onto paved roads. Because of the relatively short-term nature of construction activities, some control measures are more cost-effective than others. For example, chemical dust suppressants are generally cost-effective for relatively long-term projects with semi-permanent unpaved roads. Immediately after construction and initial landscaping are finished, the soil should be treated with chemical soil and dust binders, followed by seeding and/or restoration of vegetative coverings.

CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin that I have extrapolated to the entire basin indicates that construction and demolition accounted for about 14 percent of the fugitive soil dust emissions (with 43 percent of these emissions from residential construction, 31 percent from road construction, 13 percent from commercial construction, 9 percent from institutional construction, and 5 percent from industrial construction), about 14 percent of the phosphorus emissions, and none of the NO_x emissions. A list of PCOs for construction and demolition operations for further evaluation include:

- Apply water (i.e., wet suppression) at regular intervals (e.g., every 4 hours within 100 feet of a structure being demolished, at various intervals to disturbed areas within construction site, to disturbed soils after demolition is completed or at the end of each day) with or without a perimeter sprinkler system
- Apply chemical dust suppressants to disturbed areas
- Erect barriers around the site for soil dust sequestration
- Prohibit demolition and grading activities when wind speeds exceed 25 mph
- Require minimum soil moisture of 12 percent for earthmoving
- Limit on-site vehicle speeds to 15 mph
- Prohibit any new construction projects where soil stability is an issue
- Install a tire cleaning system at each site exit to minimize trackout of soil onto paved roads (e.g., pipe-grid system or gravel bed)
- Pave construction access roads
- Clean access roads frequently

The last three PCOs address the potential carryout of soil from the construction site onto paved roads, increasing the silt loading on the roadway surface, and increasing paved road dust emissions.

Farming Operations

Agricultural operations can be grouped into two general categories: (a) agricultural tilling, and (b) harvesting. Agricultural tilling is used for soil preparation and maintenance and is generally the dustiest of all the agricultural operations. It includes plowing, harrowing, land leveling, disking, and cultivating. Harvesting is usually performed once per crop, and the method of harvesting is highly crop-dependent. Since the largest sources of agricultural emissions are those related to soil working operations, the most effective control strategies are those related to minimizing their emissions or entirely eliminating those steps where possible. Control techniques to minimize fugitive dust from agricultural operations include process modifications of various tillage operations as well as tilling and harvesting prohibitions on high-wind days. Process modifications to soil tilling include using novel implements or changing techniques to eliminate some tilling operations altogether. The no-till and minimum till farming methods developed to minimize topsoil erosion, conserve water, and reduce dust emissions fall into this category as does the use of herbicides for weed control. An effective control strategy will probably include several of these control methods since any one method is limited in scope.

CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin that I have extrapolated to the entire basin indicates that farming operations accounted for about 2 percent of the fugitive soil dust emissions (with 85 percent of these emissions from agricultural tilling and 15 percent from agricultural harvesting), less than 2 percent of the phosphorus emissions, and none of the NO_x emissions. A list of PCOs for farming operations for further evaluation include:

- Equipment modification
- Process modification
- Limited activity during high winds

Mobile Sources

Mobile sources include both on-road vehicles traveling on paved and unpaved roads as well as other modes of transportation (aircraft, boats) and off-road sources (primarily construction equipment). CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin indicates that mobile source exhaust emissions accounted for none of the fugitive soil dust or phosphorus emissions, and about 90 percent of the NO_x emissions. A list of PCOs for mobile sources for further evaluation include:

- Provide trolley or elevated tram service
- Institute ski shuttle services
- Institute inter-city bus services for casino guests
- Facilitate non-motorized transportation (bike lanes, electric golf carts)
- Provide incentives for the use of bike lanes
- Create a pedestrian friendly environment
- Provide incentives for alternative fuel use
- Develop mass transit incentives
- Provide incentives for mandatory employer-based trip reduction programs
- Provide incentives for alternate driving days
- Provide incentives for vanpools for commuters
- Provide incentives for ferry travel to reduce travel on roads
- Traffic signal synchronization to minimize vehicle idling time
- Prohibit recreational boating during late evening/early morning hours when atmospheric dispersion is low
- Annual Smog Check for cars older than 4 years with no exemptions for old cars
- Reduce commercial boating activities
- Limit travel during late evening/early morning hours when atmospheric dispersion is low
- Require particulate filters for diesel trucks and buses
- Require particulate filters and/or oxidation catalysts for diesel powered boats
- Retrofit vehicles/boats with cleaner engines
- Inspection program for off-road equipment
- Road-side inspection of heavy duty diesel trucks and buses

- Provide incentives to retire older vehicles
- Provide incentives for CA and NV residents within the air basin to purchase CA fuel

Residential Wood Combustion

CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin indicates that residential wood combustion (RWC) accounted for none of the fugitive soil dust or phosphorus emissions, and about 6 percent of the NO_x emissions. A list of PCOs for residential wood combustion for further evaluation include:

- Ban new wood burning stoves and fireplaces
- Replace non-approved stoves with EPA-certified clean burning wood stoves
- Mandatory curtailment during periods with poor atmospheric dispersion
- Limit wood burned to hardwoods or pellets with low moisture content
- Weatherize residences heated by wood stoves

Managed Waste Burning

CARB's 2005 emission inventory for the California portion of the Lake Tahoe Air Basin indicates that managed waste burning accounted for none of the fugitive soil dust, about 1 percent of the phosphorus emissions, and about 1 percent of the NO_x emissions. This emission inventory indicates that managed waste burning produces ~4 percent of the total suspended particulate matter emissions with over 90 percent of this particulate matter in the fine size mode below 2.5 µm diameter. According to CARB, approximately 59 percent of the particulate emissions for this category are due to non-agricultural open burning (e.g., municipal waste, landscape refuse); another 25 percent are due to forest management, and 12 percent are due to burning of agricultural waste from field crops. A list of PCOs for managed waste burning for further evaluation include:

- Limit open burning to periods with good atmospheric dispersion (burn/no burn days)
- Ban all open burning

Appendix B. Stream Channel PCO Categories, Evaluation Methods & Bibliography

B.1. PCO Categories

Stream erosion controls such as those identified as PCOs (Table 6-3) can be viewed in terms of approach (passive or active), method (direct or indirect), spatial scale (site-specific to system-wide), intensity (modify processes to reconstruct forms), and scope (satisfying single or multiple objective). These categories may be useful for packaging and evaluating potential PCOs for the Lake Tahoe TMDL. Therefore, descriptions of categories and examples of how the PCOs may be organized is provided in (Tables B-1, B-2, B-3 and B-4).

Table B-1. Stream Erosion Controls by Approach

Type	Definition/Remarks*	Example PCOs
Passive	Cease any continuing perturbation/forcing disturbance; Remove incompatible uses	Streamside buffers; Culvert and bridge modifications; Drainage outfall modification; Remove fill/structures blocking floodplain/overbank flows
Active	Protect, repair, rehabilitate, restore the processes and/or conditions	Bank protection; Grade control; Flow regulation; Channel reconstruction Bank lowering/floodplain excavation

Table B-2. Stream Erosion Controls by Method

Type	Definition/Remarks*	Example PCOs
Direct	Increase strength/resistance to prevent erosion--in contact (armor, vegetation)	Bank protection (armor, vegetation) Excavate/reduce bank height
Indirect	Decrease stress to prevent erosion—manage or deflect flows, reduce turbulence, encourage sediment deposition	Downstream hydraulic grade control; Flow regulation

Table B-3. Stream Erosion Controls by Spatial Scale

Type	Definition/Remarks*	Example PCOs
Site-Specific	Control measures restricted to local sources, disturbances, or degraded conditions	Direct bank protection; Indirect bank protection; Bed control structure; Hydraulic control structure
System-Wide	Control measures applied to (at minimum) stream reaches and/or sub-basins	Reach-scale combination of bank stabilization, grade control

Table B-4. Stream Erosion Controls by Intensity/Scope

Term*	Definition/Remarks*	Example PCOs
Restoration	Reestablishment of the structure and function of ecosystems. Returning ecosystem as closely as possible to pre-disturbance conditions and functions. Restoration is holistic process, not achieved through isolated manipulation of individual elements.	Removal of land use and water use conflicts from channel and floodplain (meander width)-- and downstream and upstream grade control; Full channel reconstruction (modified/new planform alignment, modified/new profile)
Rehabilitation	Partial recovery of ecosystem functions and processes. Includes structural measures and assisted recovery (removal of perturbations). Rehabilitation does not necessarily reestablish predisturbance structure (but fosters geologic and hydrologic stability for ecosystems).	Bank protection; Excavate/lay back banks; Excavate/lower banks; Grade control (bed control, hydraulic control); Raise streambed elevation;
Preservation	Maintenance of current functions and characteristics to protect from future damage or losses.	Downstream bed control; Flow regulation; Bank stabilization;
Mitigation	Compensation for or alleviation of environmental damage; may occur on-site or elsewhere from damage. May recover site to socially acceptable condition, but not necessarily to a natural condition.	Stabilization of 'natural' or 'background' sources to compensate for impacted sources.
Naturalization	Establishing hydraulically and morphologically varied, dynamically stable fluvial system to support ecosystem. Does not require reference to certain pre-existing state. Socially determined and place-specific; may have or require recurring management and manipulation.	Full channel reconstruction (modified/new planform alignment, modified/new profile)
Creation	Forming a new system where one did not formerly exist. Socially determined and place-specific; may be consistent with present hydrology and morphology.	Floodplain wetlands?
Enhancement	Improving existing environmental quality. Typically modifying one or more physical attributes to benefit biological resources.	N/A
Reclamation	Modifying biophysical capacity of ecosystem, and the ecosystem. Historically associated with changes to allow utilitarian purposes (e.g., draining wetlands for agriculture)	N/A

*Source: Shields, F. D. et al. 2003

PCO Packages

Nearly all of the stream erosion PCOs can be applied as site-specific treatments, but they will be most effective and without other adverse effects if the site-specific application is restricted to locations where the problems are due to local instability and sources.

Stream erosion PCOs will most likely be applied in combinations at the reach scale. In general, several PCOs may be selected to form a 'rehabilitation', 'naturalization', or 'restoration' project. Reach scale treatment that occurs in place (vertically and laterally) would most likely be considered rehabilitation, while reach scale treatment that alters the planform, length, sinuosity and slope would be reconstruction or restoration.

B.2. PCO Effectiveness Ratings

A difficulty associated with evaluation of the stream erosion PCOs is the general lack of quantitative information to predict performance…either as individual elements or when combined in comprehensive and/or geographically extensive treatments.

Even stream rehabilitation and restoration manuals that provide detailed design guidance lack quantitative information to predict effectiveness (FISRWG 1999; Watson, et al 1999; River Restoration Centre 2002). However, case study descriptions and subsequent performance observations are provided, along with some considerations to improve the effectiveness of measures. Despite progress in the tools available to simulate stream processes, the inherent complexity of river processes, channel form, and aquatic and riparian ecology, limit the ability and certainty of predicting river channel response to specific alterations, "…each restoration project can best be viewed as an experiment"(Kondolf 2006 website). Advances in design and monitoring of stream projects has been rapid over the last decade, but extrapolation of empirical performance information between regions and even between systems within regions is often inappropriate.

Results of the CONCEPTS modeling will provide feedback on performance of some PCOs that can be used in refining the effectiveness rating prior to draft load reduction estimates.

Guidelines for stone bank armor have been thoroughly analyzed by research and practical application…can be designed with high degree of precision (Watson et al. 1999). There are also similar levels of design/performance information available through research and engineering standards for other direct bank protection. However, most performance or design guidance data for biotechnical and mixed material treatments are empirically based (Larson et al., 2001; D'Aoust and Millar 2000; Micheli and Kirchner 2002a; Micheli and Kirchner 2002b). There are no formal or widely-tested criteria exist for indirect protection (e.g., dikes, retards, vanes) and limited guidance for use of flow regulation (Watson et al. 1999). Studies of the effects of riparian vegetation on bank stability and channel recovery can depend on basin-wide factors, spatial and temporal context of specific reaches, and may take longer and involve different processes than the original destabilization (Jacobson and Pugh 1990). Some recent studies combining field and modeling techniques provide indications of the expected effect of different riparian species on bank stability (Pollen and Simon, 2005; Simon et. al., 2006).

Efforts towards long-term water quality and ecosystem monitoring have increased (Palmer et al 2005), but there is still limited guidance for expected 'effectivity' of PCOs from empirical data. The National River Restoration Science Synthesis (NRRSS) is an effort to analyze the extent, nature, scientific basis and success of stream/river restoration projects nationwide, with California as one of the seven regional nodes. Post-Project Appraisals of California stream restoration projects conducted for the NRRSS study (Kondolf, G. M. et al in review and NRRSS database) would be examined as source of data for PCO evaluation.

Effectiveness monitoring of stream projects in Tahoe, as elsewhere, has been conducted with reference to project-specific objectives (qualitative and/or quantitative) and at project-level spatial scales (EDAW 2006). Few projects have long or readily available monitoring records, or specific parameters related to fine sediment. Some projects have at least a few years' post-construction data, which would be reviewed for guidance on PCO effectiveness. Contributors, especially project owners and sponsors that have ongoing baseline or post-project performance monitoring (e.g., California State Parks, USGS, USFS, and CTC) will be a source of data for the initial PCO effectiveness rating. For example, some local monitoring results that can be used to develop effectiveness ratings include:

- Post-restoration monitoring of the Trout Creek Stream Restoration and Wildlife Habitat Enhancement Project (since 2001) has included a range of parameters (River Run 2006; Swanson Hydrology and Geomorphology 2004; Wigart 2003; and Herbst 2003). Several components of the monitoring results provide qualitative and quantitative guidance for estimating effectiveness of process-oriented full channel restoration and some site specific treatments (e.g., sod revetment bank protection).

- Post-restoration monitoring associated with the 2003 reconstruction of lower Rosewood Creek provides some seasonally- and event- varied data of changes in suspended sediment loads (Susfalk 2006). These data provide quantitative indications of effectiveness for similar channel reconstruction/rehabilitation (at least for initial years, and/or with flow regulation) and some site-specific treatments (e.g., stone bank toe protection, grade control).

- Suspended sediment sampling in the Upper Truckee Marsh on a functional stream (Trout Creek) and an impacted, incised channel (Upper Truckee River) by Stubblefield et al. (2006) identified improved sediment retention percentages on the portion of marsh with better floodplain connectivity. These data provide quantitative indications of possible effectiveness of PCOS that improve floodplain connectivity (at least in very low gradient reaches).

Many of the stream restoration projects in Lake Tahoe have a wide range of project objectives, and varied priorities by owners and sponsors. In the absence of required uniform evaluation techniques (e.g., modeling simulations) or reliable treatment effectiveness information, pre-project alternatives evaluations have largely been subjective, relative/ranking, with some use of hydraulic modeling to generate semi-quantitative results (e.g., EDAW and ENTRIX, 1999; TRCD 2003; Swanson Hydrology + Geomorphology 2004; EDAW & ENTRIX 2005; Mainstream Restoration 2005; ENTRIX 2006). These analyses have incorporated criteria related to restoration of natural stream processes and functions that are proxy indicators of expected water quality improvements, such as:

- improved floodplain connectivity and resultant increased overbanking frequency;
- increased channel length and inundation area from frequent overbanking (without high floodplain velocities or shear stress);
- reduced bank erosion (reduced channel length of ‘high’, erodible, and eroding banks);
- increased streamside riparian vegetation; and,
- control of channel incision (grade control).

B.3. Issues and Uncertainties

Data from both the semi-quantitative and quantitative analyses will require expressions and explanations of uncertainty in the results. Several areas of uncertainty relate to PCO effectiveness:

- lack of quantitative, tested and reliable means to predict effectiveness of PCOs –as designed, as constructed, and as maintained;
- variable performance of PCOs over life span
- driving effects of trends and cycles in weather and climate that affect initial and long term performance of PCOs

There will be issues to describe about the geographic application of PCOs, decisions about treatable and untreatable reaches.

There will be issues about the selection of 'best' or maximum load reduction PCOs versus some other more 'practical' or multiple objective PCOs.

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